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This study, prepared pursuant to Public Act 79-790, examines the economic impacts expected to result from the application of noise limitation standards to the impact forging industry in Illinois. Section I of the study reviews the background of the problem and alternative remedies that have been proposed. Section II assesses the costs on state and local government and on Illinois agriculture. The potential effects on prices, employment, and industrial activity are alos considered. Section III of the study reviews the benefits that alternative reductions in forging noise might be expected to bring, provides a measure of these benefits, and compares benefits with costs on both an overall and an incremental basis.

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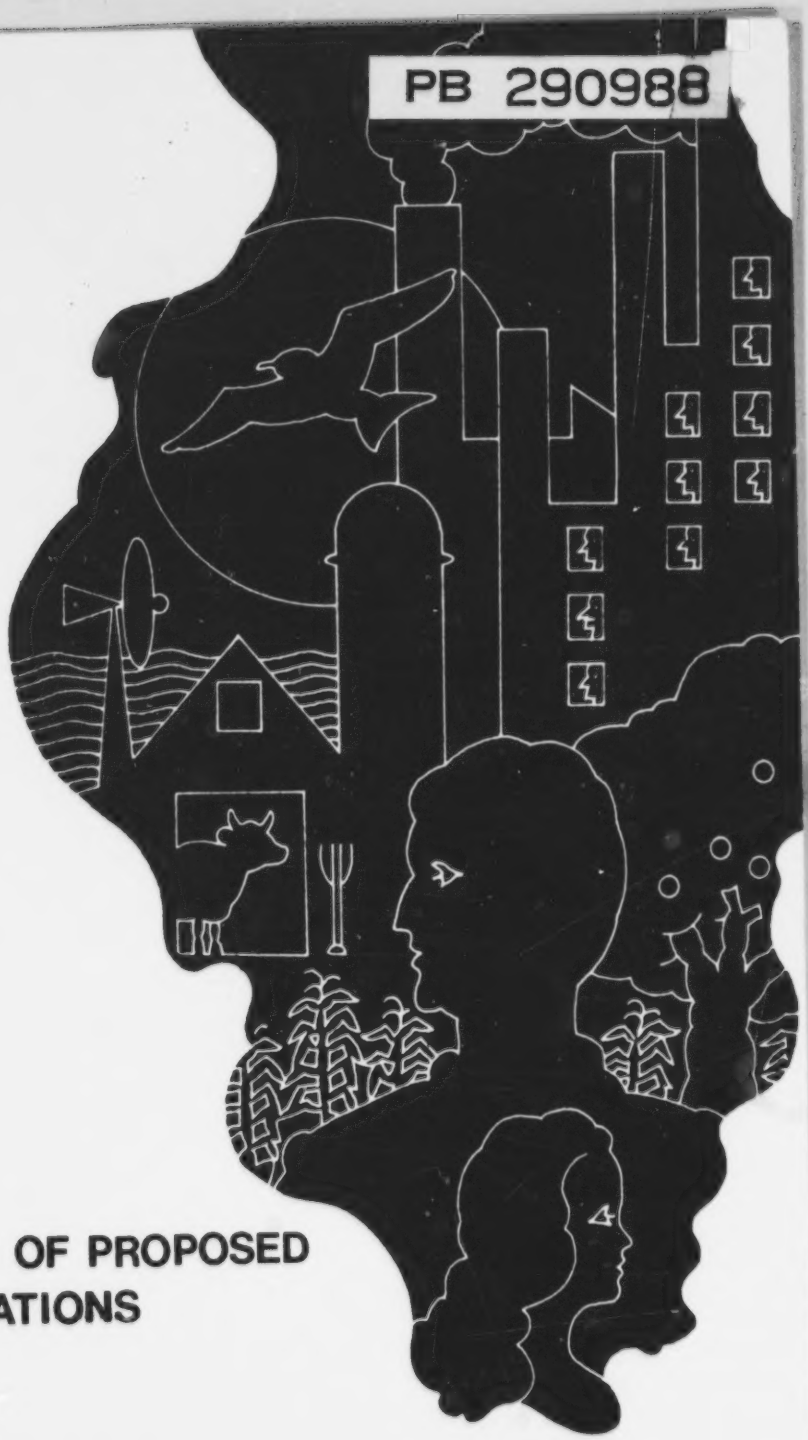

THE ECONOMIC IMPACT OF PROPOSED FORGING NOISE REGULATIONS (R76-14, -19)

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THE ECONOMIC IMPACT OF PROPOSED FORGING NOISE REGULATIONS

(R76-14, -19)

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NOTE

This report has been reviewed by the Institute of Natural Resources and approved for publication. With the exception of the Opinion of the Institute's Economic Technical Advisory Committee, views expressed are those of the contractor and do not necessarily reflect the position of the IINR.

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Opinion of the Economic Technical Advisory Committee of the Illinois Institute of Natural Resources

The Economic Technical Advisory Committee has reviewed the economic impact study Document No. 78/03 entitled The Economic Impact of Proposed Forging Noise Regulations, R76-14, -19. The Committee finds the report to be generally responsive to the requirements of Section 6 of the Environmental Protection Act and recommends that it be forwarded to the Pollution Control Board so that public economic impact hearings may be held in conjunction with proposed regulations, R76-14, -19.

Approved: October 4, 1978

EXECUTIVE SUMMARY

This study, prepared pursuant to Public Act 79-790, examines the economic impacts expected to result from the application of noise limitation standards to the impact forging industry in Illinois. Section I of the study reviews the background of the problem and alternative remedies that have been proposed. Section II assesses the costs of alternative standards to the industry and the impact of these costs on state and local government and on Illinois agriculture. The potential effects on prices, employment, and industrial activity are also considered. Section III of the study reviews the benefits that alternative reductions in forging noise might be expected to bring, provides a measure of those benefits, and compares benefits with costs on both an overall and an incremental basis.

Three main measures of cost are calculated. The first is a set of base case estimates of the costs to the Illinois forging industry of meeting the current 56 dB(A) impulsive noise standard and alternative, less restrictive, standards. These estimates contain a capital cost component associated with the structural modification of forge shops, and an operating cost component associated with the use of mechanical ventilating systems. Estimated total costs are $38.1 million for a 56 dB(A) standard, $28.4 million for a 61 dB(A) standard, and $20.9 million for a 66 dB(A) standard. These figures are subject to several possible sources of error, which are examined. Two of the more important sources, for example, could cause actual costs to be perhaps 40 to 50 percent lower than those estimated, and additional adjustments could reduce the figures further. However, other error sources, whose significance is difficult to judge, work in the opposite direction.

A second set of estimates gives total costs for all plants to reduce their noise emissions by 6 dB(A). These estimates are presented in response to an expressed belief that, as a practical matter, forge plants may not be able to reduce their emissions by more than 6 dB(A). The estimated costs range from $16.1 million for the group of plants not in compliance with 56 dB(A) to $11.2 million for the smaller group not presently in compliance with 66 dB(A). These figures, like those cited in the preceding paragraph, also are subject to error.

The third set of estimates covers the noise reduction costs for 10 plants subjected to individual study. The figures are presented for each plant individually and for all ten combined. These estimates serve also, through a scale-up procedure, as a cross-check on the accuracy of the statewide estimates.

Studies of the contribution that noise makes to differential property values, together with data on the distribution of housing around forge plants, provide a basis for estimating the dollar worth of benefits from forge noise reduction. The estimated statewide benefits from a 56 dB(A) standard are about $4.0 million; from a 61 dB(A) standard,

about $3.5 million; and from a 66 dB(A) standard, about $2.8 million. These benefits, as well as those accruing from more lenient noise standards, are much below the corresponding base case estimates of statewide costs. An examination of the benefit-cost balance on an incremental basis shows similar results: As one moves progressively from a lenient 86 dB(A) standard to more restrictive ones, both costs and benefits rise, but the cost increases are consistently above the benefit increases.

To test the strength of this benefit-cost balance, a variant case is developed in which costs are assumed to be 50% lower and, in accord with an alternative benefit estimation model, benefits are taken to be 70% higher. Though the excess of costs over benefits naturally diminishes, the essential outcome remains unchanged. For a 56 dB(A) standard, costs are $19.0 million and benefits $6.8 million. The corresponding figures for a 61 dB(A) standard are $14.1 million and $6.0 million, while for a 66 dB(A) standard they are $10.5 million and $4.7 million. The benefit-cost picture does not basically change when one considers an across-the-board noise reduction of 6 dB(A) per plant. In this case, depending on the number of plants affected, benefits are but one-fifth to one-sixth of costs.

A final set of benefit-cost comparisons is presented covering ten plants individually and as a group. These comparisons are consistent with those based on statewide figures. For all of the individual plants, benefits are less than costs, though by amounts that vary widely. In only one case is the margin sufficiently small that a modest adjustment in the figures would reverse the outcome. For the plants as a group, for each alternative noise standard, benefits again are below costs. The margins, however, are narrower than those found previously for the statewide base case. At 66 dB(A), for example, benefits are $1.3 million and costs $4.1 million. As a limiting case, for the same group of plants, the "wall-by-wall" cost estimates of ETA Engineering are used in conjunction with the augmented benefit figures cited above. The resulting comparison shows that benefits rise above costs for noise standards in the 69-81 dB(A) range. It shows also an equality between marginal costs and benefits at 75-76 dB(A).

The noise limitation standards that ultimately are adopted could, if sufficiently stringent, impose a significant cost burden on the Illinois forging industry. In consequence, the contingency exists that the industry's growth and employment will be held to lower levels than would otherwise prevail. The prospective outcome cannot be forecast with any assurance. It can be said, conditionally, that each percentage point by which the industry shrinks or fails to grow would entail a loss of perhaps 55 jobs and $3 million in revenues.

The adoption of forging noise standards, whether at the 56 dB(A) level or a less restrictive one, is not expected to generate significant costs to Illinois governments or to Illinois agriculture, since forgings constitute a relatively small component in the values of the items that these sectors purchase.

PREFACE

This study has been prepared for the Illinois Institute of Natural Resources in response to the provisions of Public Act 79-790 (1975). The Act, an amendment to the Environmental Protection Act of 1970, mandates that economic impact studies be made of all proposed environmental regulations, and amendments to such regulations, prior to their adoption by the Pollution Control Board.

Preparation of the study has been greatly facilitated by cooperation and assistance from staff in the Institute, the Environmental Protection Agency, and the Forging Industry Association, and from other individuals. Special thanks for assistance at various points are due James R. Bullock, Roger W. Findley, Thomas G. Getz, Robert D. Hellweg, Alfred A. Hendrickson, William J. Murphy, Michael F. Nechvetal, Rein Pirn and Paul D. Schomer. However, none of these individuals is responsible for the views expressed in the study or for deficiencies that it may contain. Any errors of fact or interpretation are attributable solely to the author.

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I. INTRODUCTION

A. The Problem and Its Background

Statewide property line noise-source regulations were promulgated in 1973 by the Illinois Pollution Control Board. The regulations, including Rule 206 governing the emission of impulsive sound, became effective on August 10 of that year, with Rule 209(h) allowing the operators of forging hammers three years in which to bring their activities into compliance with the new noise standards. Although the three year period has now expired, the great majority of forging plants have not achieved compliance. Meanwhile inquiries have been undertaken, both through industry sponsorship and by the Illinois EPA, to determine whether those not in compliance would be able to meet the 1973 standards and, if not, what changes in those standards might be justified. As a result of these inquiries, the Forging Industry Association (FIA) has proposed a revised set of standards. The Illinois EPA has also proposed a set of standards which differ in certain respects from those of the Association. The FIA and the IEPA proposals are contained in Appendix II. Both the current and the proposed revised standards for impulsive sound emissions from Class C (industrial) property on which impact forging operations are conducted to Class A (residential), Class B (commercial), and Class C properties are summarized below.

Proponent	Receiver			
	C	B	A	
			Day	Night
Current	65 dB(A)	61	56	46
EPA	---	72	61	56
FIA	---	72	66	56
FIA (new plants)	---	67	61	51
EPA (new plants)	---	67	61	51

The standards refer to measurement with the meter set for A-weighted "fast" response.

As the table shows, both the IEPA and the FIA propose the elimination of standards governing forge plant emissions to other Class C properties. Both agree on the standards for Class B property, the standards for new plants, and the standards for nighttime operations. Disagreement centers on the daytime standard for Class A property, with the current regulation at 56 dB(A) and the proposed alternatives of 61 and 66 dB(A).

The EPA and the FIA also disagree over the procedures that should operate in working toward attainment of whatever standards are set. The EPA endorses the customary mechanism of granting variances to plants for which compliance would be technically infeasible or economically unreasonable. The FIA recommends that plants unable to comply prepare and file noise control plans and that, subsequently, the Pollution Control Board establish noise standards appropriate to each such plant. These alternative procedures are not an explicit subject for review in this study, though note is taken of their respective cost implications.

The Community Noise Survey (cited below) undertaken jointly by staff from the Illinois EPA and Michigan Technological University indicates there is but a very limited problem for Class B properties arising from forging noise emissions; the Survey found only two instances of violation of the current 61 dB(A) standard. In contrast, the Survey found numerous violations from such emissions to Class C properties, and many of these would remain even if sufficient noise reduction occurred

to meet the current standard for Class A land. For present purposes, this problem may be understood as a part of the more general problem of noise emissions from one industrial property to another. The standards limiting such emissions have been proposed for elimination and are currently the subject of a separate IEQ study. Accordingly, they are not dealt with in the present study.

The proposed standards agreed upon by the Agency and the FIA for new plants, more restrictive than those proposed for existing plants, do not appear to pose a problem. In the construction of new plants, the technical means are available to achieve somewhat lower noise levels than was possible in earlier years. Also, suitable siting and land acquisition can minimize noise impacts on neighbors. While the Agency and the FIA are in agreement regarding the standards for nighttime operation--5 to 10 dB(A) more restrictive than for daytime operations--enforcement could bring difficulties and higher costs for existing plants. Brief consideration is given to this issue in Section II.

The current and proposed daytime standards for Class A properties comprise the main area of disagreement and are the subject given predominant emphasis in this study. In Section II, the costs of meeting the alternative daytime standards are considered, while Section III develops benefit estimates for these standards and compares them with costs.[1]

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[1]The Occupational Safety and Health Administration has established noise standards that would limit an employee's noise exposure to 90 dB(A), as an eight-hour time-weighted average. These standards also recommend that exposure to impulsive or impact noise not exceed a 140 dB peak sound pressure level. Many Illinois forge plants are in violation of these standards, and it is not clear at the present time how or whether these violations may be rectified. If compliance with the O.S.H.A. standards were ultimately to be achieved by quieting at the source, some favorable effects on external noise emissions might be realized. Meanwhile the existence of these standards does not alter in any way the technical and economic problems involved in achieving reductions in the external emissions of forging noise, nor does it alter the costs and benefits that would result from such reductions.

B. Some Characteristics of the Illinois Forging Industry

Impact forging involves the manufacture of metal goods through "a shaping process, accomplished through controlled plastic deformation which permanently alters the shape and internal structure of the metal. The alteration improves the metal's mechanical properties and capabilities. The forgings are shaped with dies . . . The pressure needed to shape the metal is supplied by the impact of the upper die, which is fastened to a guided ram, falling or driven against the lower die, which is fastened to an anvil . . . The sound produced . . . is impulsive in nature and orginates primarily from the impact between the upper die and the workpiece and lower die."[1]

The metal goods produced through impact forging are widely used. The end products in which they are incorporated include automobiles, trucks, aircraft, railroad equipment, refrigeration and heating units, oil field machinery, ordnance, internal combustion engines and mechanical power transmission equipment.[2]

There are 43 impact forge plants in Illinois.[3] According to the U. S. Census of Manufacturers, in 1972 these plants employed 5600 persons, met payrolls of $63.7 million and shipped goods worth $229.7 million.[4] However, these figures may be too low. When forging plants

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[1]"Proposal to Amend the Noise Regulations, Rules 101 and 206," FIA submission to the Pollution Control Board (R76-14), pp. 2-3.

[2]Ibid., pp. 3-4.

[3]The EPA-MTU Community Noise Survey lists 45 plants, but two of these, Fox Valley and Jernberg, use upsetters rather than hammers.

[4]The Census shows 44 establishments. Though we cannot be sure, it seems likely that this figure covers all, or virtually all, of the 43 impact forge plants.

are elements in a larger, integrated set of production activities, as sometimes occurs, some of their employment, payrolls and shipments may be classified to the industries that use their products. The FIA, on the basis of its own survey data for 1976 covering 37 Illinois forging plants, reports employment of 8,228 and sales volume of $508 million.[1]

Growth in the Illinois forging industry has been slow or negligible in recent years. Over this period, only one new plant has been established--the Wyman-Gordon facility in Danville (which uses presses rather than hammers). The Census reports a small decline in forging industry employment in the State between 1967 and 1972.

The Illinois segment of the forging industry serves national as well as state markets, though shipping costs limit market range for basic products. A survey of Illinois firms by ETA Engineering[2] suggests that a substantial fraction of forging output is shipped out-of-state. The main competition for Illinois plants comes from the nearby states of Wisconsin, with a census count[3] of 31 plants, Ohio with 47 plants, Indiana with 10 plants, and Michigan with 7 plants.

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[1] Letter to William J. Murphy from the Forging Industry Association, dated February 24, 1978. The Association, in its "Proposal to Amend the Noise Regulations . . ." gives 1975 estimates of employment of 6000, of payrolls in excess of $95 million, and of shipments of over $345 million.

[2] The Economic Impact of Impulsive Noise Standards on the Illinois Forging Industry, April 1977 (Oakbrook, Illinois).

[3] Subject to the kind of classification error previously noted.

II. THE COSTS OF NOISE REDUCTION

A. Types of Costs Considered

Three types of costs might be expected to arise directly from efforts by the forging industry to comply with a regulation limiting impulsive noise emissions. First, there are the costs of physically altering the forge plant structure, through the reduction or closure of openings, the addition of acoustically absorbent materials, the installation of shielding, and other such actions so as to reduce the noise emitted to surrounding properties. Second, there are certain capital and operating costs arising from the use of the heavy duty, expensive ventilating equipment that generally is required when a plant is modified to reduce noise. Third, there are the costs incurred through hearings before the Pollution Control Board to grant or extend variances or establish separate regulations for individual plants. These costs arise from the activities of all the participants in a regulatory proceeding--the forging companies, the Illinois Environmental Protection Agency, the Pollution Control Board, expert witnesses, and any affected citizens.

Certain other costs, less direct and contingent upon the circumstances that may materialize or the assumptions made, may also be incurred. One such cost would be that resulting from a plant shutdown because of inability to meet a noise standard and to obtain a variance. The inability to comply could arise from technical or from economic considerations or from some combination of them. The consequent costs would take the form of lost revenues, profits and jobs in the State. A related type of cost would be that deriving from any burdens the standards might place on the expansion of present forging plants or the attraction to the State

of new forging operations. The loss in these instances would, similarly, involve foregone revenues and jobs. Yet another cost would be that associated with a weakening of the competitive position of Illinois forge plants as a result of higher costs. Again, lost revenues and jobs would be involved.

Each of these kinds of costs is reviewed below. The bulk of attention is given to the cost of structural alterations in forge plants, since it is the largest and most immediate of the costs to be reckoned with in considering a regulatory standard. Treatment of the other elements, while briefer, should serve to indicate the approximate significance of each. It deserves note that contingent and indirect costs like foregone revenues and employment are especially difficult to assess, and estimates of them are unavoidably quite speculative.

Changes in product costs can generally be expected to lead to increases in prices to the users of those products. The potential for such increases is also considered briefly in the analysis that follows, and attention is given to the possible impact of any such increases on Illinois agriculture and on state and local government.

B. Noise Status of Illinois Forge Shops

The State's 43 impact forging plants, covering 53 shops, are subject to the impulsive noise limits under Rule 206. A study undertaken jointly by Michigan Technological University and the Illinois Environmental Protection Agency[1] indicates that 26 of these plants, covering 34 shops, are

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[1] Community Noise Survey of Illinois Forge Plants, Vols. 1-3. IEPA DNPC Tech. Report No. 76-1,2,3, September, 1976. Hereafter referred to as the EPA-MTU Noise Survey.

in violation of the current daytime impulsive noise limit of 56 dB(A)[1] for Class A land. The plants in violation taken as a group, do not appear to be inherently noisier or built to lower standards than the plants in compliance. Rather they have the disadvantage of being located more closely to residential properties. This proximity has resulted in part from the insufficiency of adjacent land owned by the plants and in part from the way zoning patterns and residential development have occurred over time.

The plants in violation are listed in Table 1, together with the respective noise levels recorded at the nearest residential property. Table 2 rearranges this information to show a distribution of forge shops by noise level intervals. The available data do not permit the shops of multiple shop plants to be identified in terms of their noise emissions on an individual basis, and hence all the shops of a given plant are treated in Table 2 as if they shared a common noise level.[2]

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[1]The A scale is generally preferred in gauging human response, since its weighting system approximates that of the human ear. The C scale gives greater emphasis to the lower frequencies and might, for example, be used in situations involving vibration problems. The linear peak measure has no correlates in the literature to human response, and there is no standard instrumentation for measuring it.

Vibration as an accompaniment of the external transmission of forge noise has not been reported as a problem presumably because of an insufficiency of the requisite lower frequencies. The ground transmission of vibration from hammer impacts is possible, but does not seem to occur to any extent.

[2]This treatment gives the resulting cost figures a possible upward bias. An alternative approach, which seems somewhat less plausible, would be to treat the observed noise level of a multiple shop plant as applicable to only one shop, with the other shop (or shops) in compliance.

Table 1

Plants in Violation of the 56 dB(A) Standard

Plant	Noise level at nearest residence in dB(A)
Amforge (Great Lakes) (11)	82
Anchor Harvey (41)	66
Armstrong Bros. (3)	73
Atlas (7)	90
Blue Island (38)	79
Brunner and Lay (42)	90
C. S. Norcross (18)	80
Chambers, Bering and Quinlan (24)	80
Clifford Jacobs (23)	67
Cornell (Hampshire) (14)	60
Crescent (32)	63
Damascus (35)	64
DeKalb (15)	64
Estwing (34)	61
Forgings and Stampings (25)	88
Fred Bromm (37)	70
International Harvester (20)	79
Modern (28)	75
Moline (17)	74
Rockford (26)	67
Star (39)	86
Snap-on-Tools (22)	61
Universal (29)	61
Vaughn and Bushnell (19)	69
Wyman-Gordon-Harvey (27)	76
West Chicago (31)	67

Source: See text. Numbers at the right of each name are the identification numbers in the EPA-MTU noise survey.

Table 2

Distribution of 34 Non-Complying Forge Shops by Noise Levels in Excess of 56 dB(A)*

dB(A) Range	Exceeds 56 dB(A) by	Number of shops	Percent of shops
57-61	1- 5	4	11.76
62-66	6-10	4	11.76
67-71	11-15	5	14.71
72-76	16-20	8	23.53
77-81	21-25	7	20.59
82-86	26-30	3	8.82
87-91	31-35	3	8.82

Source: Table 1.

*All shops in multiple shop plants are classified in the same way as the shop subjected to measurement.

From Table 2, one can readily determine not only the number of shops that would be in violation of any standard, but also the extent to which the various groups of shops would have to reduce their noise emissions in order to comply. Thus, to meet the I.E.P.A.'s proposed 61 dB(A) standard, 30 shops would have to reduce their emissions--4 by 1-5 dB(A), 5 by 6-10 dB(A), 8 by 11-15 dB(A), etc. Raising the standard to 66 dB(A) would reduce the number of shops required to make some reduction to 26; but even with a standard of 71 dB, 21 shops would not be in compliance.

C. Cost Estimating Methodology

The cost of reducing forge shop noise emissions by varying amounts has been the subject of a special study for the Forging Industry Association by Rein Pirn of Bolt, Beranek and Newman, Inc.[1] The study provides a systematic approach to the subject, along with cost estimates and an extensive data base. It is relied on in the present report as a source for developing adjusted statewide cost estimates, with these estimates in turn serving as a baseline for further analysis.

There is a considerable diversity among Illinois forge plants in physical characteristics and in siting. The BBN approach recognizes this diversity and seeks to accommodate it, while at the same time avoiding the need to make estimates on a plant-by-plant basis. The BBN estimating model is built upon the following series of steps:

a. Six plants, regarded by the study's author as representative of existing forge shop structures, were selected to serve as a basis for identifying the essential acoustical characteristics of forge shop structures.

> "These particular plants represent a good cross-section of the recorded acoustical situations (including cases that partially comply with . . . Rule 206, and cases that exceed it by more than 30 dB), and appear quite typical of the industrial architecture of forging plants."[2]

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[1] Hammer Noise Emission of Illinois Forging Plants, Final Report, December 9, 1976. (BBN Report No. 3400.) Hereafter referred to as BBN 3400.

[2] BBN 3400, p. 6. The six plants are Amforge (Great Lakes), Anderson-Shumaker, Armstrong Brothers Tool, Atlas Forgings, Kropp Forge, and Wyman-Gordon.

b. From these six plants, some of which covered multiple shops, 14 elevations were identified as distinguishable cases and subjected to further examination. These elevations are treated essentially as representative of all forge shop elevations in the State. The author refers to them as being "pivotal" to his entire study.[1]

c. The dimensions of an average or typical elevation are estimated to be 210' x 35 1/4', for an area of 7400 square feet. This estimate is based on a statewide sampling of 26 cases rather than on the selected 14 elevations, since the latter are believed to cover some unusually large forge shops.[2] The estimate forms the dimensional basis for a "reference structure" in terms of which improvement costs are later estimated.

d. Through analysis of the physical characteristics of the 14 elevations, a structural-compositional profile of the reference structure is developed. The reference structure thus "...typifies the scale, physical nature, and acoustical properties of Illinois forge shops...".[3]

e. Alternative methods are identified, applicable to the reference structure, for reducing noise emissions by each successive 5 dB increment. The cost of applying each of these methods is then estimated with the aid of engineering cost data supplied by the architectural-engineering firm of Holabird and Root.[4] Finally, the frequency

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[1] BBN 3400, p. 7.

[2] BBN 3400, p. 8.

[3] BBN 3400, p. 25.

[4] Cost Estimate for Suggested Improvements of Hammer Noise Emission of Illinois Forging Plants, Chicago, December 1, 1976. Hereafter referred to as Holabird and Root.

of applicability of each method is determined by reference to the actual characteristics of each elevation in the sample of 14.

f. On the basis of an examination of ten forge plants (12 shops),[1] particularly with regard to their siting and the exposure of their sides to potentially impacted homes, the author estimates that 2.5 of a forge shop's 4 sides typically must be subjected to improvement in order to attain any specified degree of quieting. He further estimates that an additional 0.9 side that is exposed but not facing impacted homes must also be improved, but by 15 dB less than the 2.5 facing sides. The remaining 0.6 side requires no modification.

The model that incorporates the foregoing essential features serves, in effect, to indicate both the cost of quieting a forge shop by any given amount, by alternative methods, and the frequency of applicability of each of those methods. It thus can be applied to the State's population of forge shops, to estimate the aggregate cost of bringing that population into compliance with any given regulatory standard.

D. Estimated Statewide Capital Costs

The statewide costs of meeting alternative noise standards, as estimated from the BBN model and adjusted by the present writer, are shown in Table 3 and Figure 1. In preparing its estimates, BBN necessarily relied on the EPA-MTU Noise Survey to determine the incidence and degree of non-compliance among forge shops. The Survey was incomplete at the

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[1] The plants are the same as the 10 later subjected by the author to individual cost analysis. These plants also serve as the basis for the benefit-cost assessment by ETA, Inc. These findings are discussed below.

Table 3

Estimated Statewide Capital Costs to Meet
Alternative Regulatory Standards for Class A Land

Regulatory Standard dB(A)	Estimated Cost (in millions)
56	$28.11
61	20.22
66	14.66
71	9.75
76	4.94
81	2.11
86	0.82

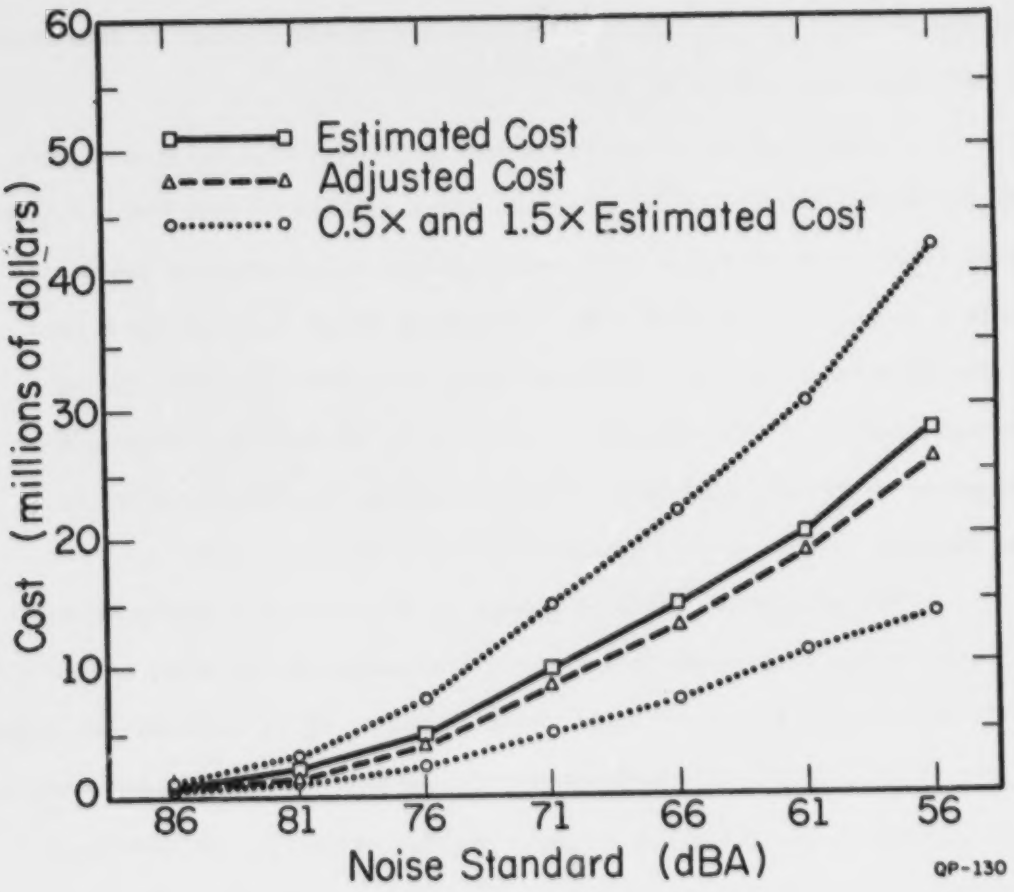
Source: See text.

time, and subsequent data altered the results somewhat. The figures in Table 3 and Figure 1 incorporate these later data (as summarized in Table 2), and hence they differ slightly from those estimated by BBN.[1]

Henceforth in this report these estimates will be treated as the basic statewide estimates and used for reference purposes. The estimates cover the costs of structural alterations, including the installation of ventilating equipment where needed. They relate only to noise standards for Class A land. The problem with respect to Class B land appears to be minimal, since few violations of the existing Class B standard (61 dB(A)) were observed in the EPA-MTU Noise Survey.[2] The

[1] Figure 11, p. 76, in BBN 3400 summarizes the BBN estimates.

[2] Only two instances of Class B violations are reported in the Survey.



ESTIMATED STATEWIDE CAPITAL COSTS TO MEET ALTERNATIVE REGULATORY STANDARDS

Figure 1

problem with respect to Class C land under the current standard (65 dB(A)) is substantial. However, both the I.E.P.A. and the F.I.A. have recommended that there be no noise standard for this property category. Should it happen that the standard governing noise emissions to Class C property is not eliminated or revised upward, the estimated costs to the forging industry of compliance with the noise standards will be substantially higher than those indicated here.[1]

Table 3 shows an aggregate cost of about $14.7 million to meet the FIA proposed limit of 66 dB(A) and $20.2 million to meet the E.P.A. proposed limit. The burden of this cost would be quite unevenly shared, as Table 2 suggests, because of wide differences among shops in the needed degree of noise reduction. The underlying data indicate that, for an average plant, a 25 dB reduction would cost $1.065 million, while a 5 dB reduction would cost $295,000. Shops already in compliance (of which, for 56 dB(A), there are 17) would, of course, incur no costs.

The statewide estimates, based as they are on a synthetic model of forge shops, with parameters derived from samplings of data, are unavoidably subject to a margin of error whose magnitude it is difficult to judge. Errors in certain of these parameters--the average number of sides requiring correction, the frequency of applicability of particular methods of quieting, the cost of implementing a given method--could make for significant errors in the statewide figures. This issue is considered further in the next paragraphs.

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[1] The higher costs would arise from two sources. First, there are 14 Illinois forge plants presently in compliance with the Class A standard that are not in compliance with the Class C standard. Second, there are 13 plants not now in compliance with the Class A standard for which achievement of compliance with that standard would not suffice for compliance with the Class C standard.

As a complement to preparing statewide cost estimates, BBN also developed estimates of the costs to meet regulatory standards for each of 10 individual forge plants, covering a total of 12 forge shops.[1] This set of estimates offers a means for a useful, though nonconclusive check on the figures in Table 3. It is nonconclusive because the individual estimates are made through reference to the same cost parameters and quieting methods contained in the statewide estimating model. At the same time, the individual estimates incorporate information that is plant specific--primarily, the number of exposed sides and the suitability of a plant to any particular method of noise reduction.

The combined cost for all 12 shops of meeting alternative regulatory standards is shown in Table 4, column 1. If we assume these shops to be representative of all 34 non-complying shops, then we can project the figures to a statewide basis by multiplying each of them by 34/12. The results of this adjustment are shown in column 2. Column 3 incorporates a further adjustment to correct for the disparity between the area of a typical elevation as used in the model (7400 square feet) and the average of an elevation for the sample of 12 shops (5400 square feet).[2]

The results in column 3 are plotted in Figure 1 and connected by the dashed line. The differences between projections based on the 12

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[1] BBN 3400, Section H.

[2] The data used to derive the average area of an elevation of the 12-shop sample are those shown in BBN 3400; pp. 85-100. The areas of elevations not requiring improvement are not shown and were not included in the calculation of the average.

Table 4

Statewide Capital Costs as Estimated From Data on 12 Shops
(in millions)

dB(A) Level	(1) Combined cost 12 shops	(2) "Equivalent" statewide cost[1/]	(3) Adjusted statewide cost[2/]
56	$6.69	$18.94	$25.93
61	4.83	13.68	18.73
66	3.37	9.55	13.07
71	2.17	6.15	8.42
76	1.04	2.95	4.03
81	0.38	1.07	1.46
86	0.19	0.54	0.74

[1/] Column (1) x 34/12.

[2/] Column (2) x 7400/5406.

shop sample and the statewide estimates in Table 3 are relatively large at the higher dB levels where the cost figures are low. For 81 dB(A), for example, the 12-shop projections are about 30 percent below the statewide estimates, and for 76 dB(A) they are about 18% low. But at the lower dB levels, the differences are much smaller, and taken overall they could be described as nominal. This outcome suggests a consistency between the statewide estimates based on the general model and those that might have been obtained through a more detailed assessment of each of the 34 non-complying shops.

However, a qualification must be added to this statement. The 12

shops subjected to individual study appear on the average to be no smaller and are possibly rather larger, than the average non-complying shop. This possibility is suggested by a crude comparison of hammer size between the 12-shop sample and all 34 non-complying shops. For the former group, it is about 7000 pounds, while for the latter it is around 5000 pounds.[1] There is a heavy influence on this comparison of Wyman-Gordon's unusually large 25,000 pound hammer, and it is therefore helpful to repeat the comparison with this company omitted from the calculations. The resulting figures for the 11-shop sample and the larger 33-shop group are, respectively, 5000 pounds and about 4200 pounds. The difference in this case is smaller but still points in the same direction--larger average shop size for the 12-shop sample.

If, in fact, the average size of shop is larger for the 12-shop sample than for all non-complying shops, then the typical elevation should be larger for the sample group. As noted, however, it appears to be smaller--5400 square feet as compared to the 7400 square feet figure used in the general model. Moreover, on a shop-by-shop basis for the 12-shop sample, the average elevation is less than 7400 square feet for 10 of the 12 cases. This outcome suggests that the 7400 square feet figure may be too large, possibly by 35 percent or more. If so, the statewide estimates as shown in Table 3 and Figure 1 would be correspondingly overstated. In that event, the figures in column 3 of Table 4 would be a better approximation of statewide costs than the figures in Table 3.

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[1] For shops containing more than one hammer only the largest is used in calculating these figures.

The I.E.P.A., in its comments on an initial draft of this study, has maintained that even a 5,400 square foot figure for the typical forge plant elevation may be too high. Using its own significantly lower estimates of elevation areas, together with the per-square-foot cost figures obtainable from BBN 3400, it has estimated the statewide capital costs of meeting alternative standards as follows.[1]

dB(A) Level	Capital Cost (in millions)
56	(Not estimated)
61	$8.36
66	6.07
71	3.76
76	1.83
81	0.95
86	0.30

These figures fall appreciably below the corresponding figures in column 2 of Table 4 and range from about 41% (at 61 dB(A)) to 37% (at 86 dB(A)) of the basic or reference estimates given in Table 3.

There are a few additional possible sources of error in the statewide estimates, beyond those previously cited. First, the calculations underlying the statewide estimates are based on a grouping of plants and shops into 5 dB class intervals (as in Table 2) for the purpose of determin-

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[1] Communication from Robert D. Hellweg, Jr. to William Murphy of the I.I.E.Q. dated February 27, 1978.

mining the degree of quieting each must achieve to meet alternative standards. Table 2 shows, for example, that four shops presently have noise levels of between 62 and 66 dB(A). Each of these shops is treated as requiring a 10 dB(A) reduction to meet a 56 dB(A) standard. This treatment is appropriate in view of the fact that the basic cost factors to be applied had previously been developed in terms of 5 dB steps. At the same time, one might reasonably suppose that the four shops are distributed throughout the interval rather than being concentrated at its upper limit. In that case, the average shop would need only 7.5 dB(A) of quieting rather than 10 dB(A). The same consideration applies to all of the class intervals, with the needed amount of quieting reduced by 2.5 dB(A) in each case. With 34 shops affected, the total requisite dB(A) reduction for all of them would be 85 fewer than the total involved in the estimates shown in Table 3 and Figure 1. The effect of this factor on costs can be very roughly estimated. The total dB(A) reduction over all shops to meet a 56 dB(A) standard (on the upper limit assumption) is 665. The estimated total cost to meet this standard is $28.114 million (Table 3). With an 85 dB(A) downward adjustment (or an average of 2.5 dB(A) per shop), the requisite reduction falls to 580 dB(A). A revised total cost estimate may then be calculated as 580/665 x $28.114 million = $24.520 million. On this reckoning, the overstatement in the original estimate is about 13 percent. An equivalent procedure can be applied for other prospective noise limitation standards. The resulting estimated overstatement varies, but it averages about 23 percent.

A second possible source of error arises from shift-working from the late night into the early morning hours. Both the current and proposed noise regulations contain a more stringent standard for the hours of 10 p.m. to 7 a.m. than for other hours. In the current regulation and the FIA proposal, it is 10 dB(A) more stringent, while in the I.E.P.A. proposal, it is 5 dB(A) more stringent. No recognition is given this circumstance in the estimates in Table 3 and Figure 1. At least a few plants have operated during the late night period in recent past years, and a few apparently do so at the present time, though the specific numbers involved are not known. Moreover, many plants, though not operating hammers through the night, do operate them until 11 p.m. It is entirely possible that in future periods, at times of generally high levels of economic activity, appreciably larger numbers of plants will wish to operate during the nighttime hours. The cost implications of such operation might be explored by supposing that, say, five or ten shops must reduce their noise levels by 5-10 dB(A) beyond those required to meet a given daytime standard. Suppose that a daytime standard of 66 dB(A) has been met at a cost, according to Table 3, of $14.66 million. The table indicates further that the cost for all affected shops--30 of them--to move an additional 5 dB(A) to 61 dB(A) would be $5.56 million; and for all shops--now 34 of them--to move to 56 dB(A) would cost a further $7.89 million. Then the cost for, say, only five shops to meet the 10 dB(A) nighttime penalty can be calculated as follows:

$$(5/30 \times \$5.56 \text{ million}) + (5/34 \times \$7.89 \text{ million}) = \$2.09 \text{ million}$$

For ten shops, the cost would be twice as great, or $4.18 million. These figures represent respective additions to the total cost of meeting the 66 dB(A) standard of 14 percent and 28 percent. (In the limiting case

where all shops engage in night operations, the total cost of meeting the 66 dB(A) standard becomes $28.11 million, or the cost of meeting the 56 dB(A) daytime standard as shown in Table 3, and the added cost over the daytime standard is $13.45 million.)

If we consider instead an initial daytime standard of 61 dB(A), the additional cost of meeting the nighttime penalty of 5 dB would, of course, be less for five shops, $1.16 million, and for ten shops, $2.32 million, or respective additions of about 6 percent and 11 percent. Were larger numbers of shops to undertake nighttime operations, the added costs would be proportionately greater.[1]

Insofar as plants were to find these added costs of compliance in excess of their prospective net gains from nighttime operations, they would instead seek to stretch out delivery schedules or possibly be obliged to decline orders, with consequent indirect effects on their suppliers and workers. The direct costs to the plants of these actions are, as a maximum, indicated by figures estimated in the preceding paragraph.

A third source of error, of a significance difficult to assess, inheres in the potential for land use changes subsequent to actions by forge plants to comply with any established standard. Over time, in the absence of zoning restrictions, it is possible that residential development would occur on presently vacant land adjacent to forge shops, just as similar development occurred over past decades, creating new conditions of impaction. The forge shops so affected would then be liable for a fresh set of compliance outlays or, if originally in compliance, for an

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[1] A fair approximation to these figures is obtained by using $40,000 as the per shop cost of 1 dB of quieting. However, this coefficient is not reliable as a general guide in estimating the costs of quieting.

initial set of compliance expenditures. Or more likely, perhaps, would be adjacent commercial development with similar though less costly results. Some forge shops may own sufficient surrounding land or be propitiously located in built-up industrial zones, to be insulated from this problem. But for others, in the absence of protective zoning, there may be a contingent exposure to future costs for quieting.[1]

Two other factors that could affect costs should be noted.[2] First, reduction or elimination of a shop's openings--windows, doors, etc.--will raise the interior noise level; in the case of complete closure, the increase may be as much as 3 dB(A). To offset this effect, additional quieting measures, entailing additional costs, would be needed. Second, forge shops that are modified or rebuilt to reduce noise may lose some of the operating advantages of existing shops. Moreover, the undertaking of modifications may, in itself, cause interruption of production. The costs arising from these circumstances are not allowed for in the estimates.

The foregoing suggested adjustments and qualifications are unavoidably somewhat speculative as regards their quantitative significance. They should be understood not as a set of specific modifications to the estimates in Table 3, which is here used as a reference baseline, but rather as an indication of the sources of error that may exist and of their potential importance. The parallel bands around the primary estimate in Figure 1, with the lower band 50 percent below and the upper one 50 percent above this estimate serve to remind the reader that an error range exists.

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[1] BBN 3400, pp. 63-4.

[2] The FIA seeks to avoid this prospective problem by including in its proposal for revised noise standards clause 206(a)(3), which would make the current land use classification the applicable one for the setting of future, as well as present, noise standards.

E. Operating and Total Costs

When forge shop openings are closed or reduced substantially to reduce noise emissions, the system of natural ventilation is disrupted. A mechanical ventilation system then becomes essential to hold interior temperatures to tolerable levels.[1] Ventilating system equipment and

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[1] The use of mechanical ventilation as the primary or exclusive means of ventilation in forge shops is, to date, uncommon, and there is some uncertainty as to whether it can be widely and successfully applied. Dr. Alfred A. Hendrickson of Michigan Technological University, in discussions with the author, reported that he knew of but one plant, in England, that had used this approach, and that it was not entirely successful. Hence the approach might best be regarded as somewhat experimental and, as such, one that carries a potential for higher costs than the estimates would otherwise suggest. An alternative approach is to employ silencers, which are in use in both new and some older plants in West Germany. (A silencer is a structure with sound-absorbing baffles that serves to attenuate noise transmission while minimizing the reduction of air flow through the unit.) In the Hearings before the Pollution Control Board of September 22 and November 4, 1976 on the proposed limits for forging noise, there was a fair amount of testimony on the use of silencers and their potential application to the Forgings and Stampings Co. of Rockford. Based in part on this testimony, the I.E.P.A. has estimated that with silencers, a noise reduction of 15 dB(A) could be achieved at Forgings and Stampings at a cost of about $60,000, including engineering. (The estimate is offered in comments to the I.I.E.Q. on the first draft of the present study.) By contrast, the estimate for 15 dB(A) of quieting at the same plant (through the use of barriers, shop wall modifications, and the installation of mechanical ventilation) is given in BBN 3400 (p. 87) as $301,000. The applicability of silencers to Illinois forge plants is not clear from the record. It appears that their greatest potential usefulness is for achieving noise reductions of up to perhaps 15-25 dB(A) in plants of solid, heavy construction, of which Forgings and Stampings is an example. Dr. Alfred Hendrickson indicated that the approach, while appropriate for some Illinois plants, is not well-suited to many of them; they are too lightly constructed, and the resulting noise reduction would be nominal. Moreover, silencers may extend considerably beyond the thickness of the wall in which they rest, requiring clearance space inside or outside the structure and possibly interfering with productivity. Hendrickson noted that while the use of silencers saves operating costs, the capital costs involved to achieve large noise reductions may exceed those associated with mechanical ventilation. The possible use of silencers is considered in BBN 3400, but rejected as unsuitable. See p. 21 of that report.

installation costs, which constitute a major element in the cost of structural remodeling, are included in the statewide estimates given in Table 3 and Figure 1. However, additional non-negligible costs arise from the operation of the ventilating system. The major component of these costs is annual fuel costs, which are reported by Holabird and Root for the various types of ventilating systems appropriate to the several classes of (structural modification) cases.[1] The other elements of operating costs are annual maintenance costs, estimated by Holabird and Root[2] at 2-3 percent of fuel costs, and replacement at roughly 15 year intervals of selected components in the fan units--motors, bearings and fan wheels. The replacement costs, estimated to run about 2.5 percent of ventilating system equipment and installation costs, are quite small when reduced to present value. They will not, therefore, be separately identified in what follows. Maintenance costs will be taken at the upper bound of the 2-3% range, with the thought that any extra margin this may allow will serve to cover replacement costs.

The number of years over which operating costs should be reckoned for the purpose of inclusion in compliance costs is problematic. In view of the durability and long lives of forge plants, 30 years would seem a reasonable figure. The resulting 30-year stream of costs must be reduced to present values to be commensurable with the capital outlays

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[1] Holabird and Root, p. 4.

[2] In discussion with the author.

shown in Figure 1. The outcome of this calculation is, of course, sensitive to the discount rate used. For the purpose at hand, a 10 percent rate has been chosen, on grounds that it approximates the opportunity cost to forge plants of the sums involved. That is, such sums, if not spent for noise reduction purposes, might earn 10 percent if put to ordinary production purposes.

The resulting present value figures, indicating operating costs to meet alternative standards, are shown in Table 5. The use of an interval greater than 30 years, or a discount rate lower than 10 percent, would shift the figures upward, while an interval less than 30 years or a discount rate higher than 10 percent would shift them downward.[1] A comparison of Table 5 with Table 3 indicates that operating costs represent a substantial addition to the costs of structural modification. The increase varies with the noise standard chosen, but overall it would raise compliance costs by between 35 percent (at 56 dB(A)) and over 50 percent (at 86 dB(A)). In Figure 2 the two types of costs are added to get a set of combined figures. We observe that for a 66 dB(A) standard, total costs are about $20.9 million, as compared to $14.7 million for structural costs alone, and for a 61 dB(A) standard, they are about $28.4 million, as compared to structural costs alone of $20.2 million. The bands on either side of the Total Cost line are adapted from Figure 1

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[1] E.g., use of a 5 percent discount rate would yield costs about 60 percent above those shown, while a 15 percent rate would yield costs about 30 percent lower. A change in the time period of, say, 10 years either way would, by contrast have comparatively modest effects. Thus, a 40 year period would raise operating costs about 4 percent, while a 20 year period would lower them about 10 percent.

Table 5

Present Value of Operating Costs to Meet Alternative Noise Standards*

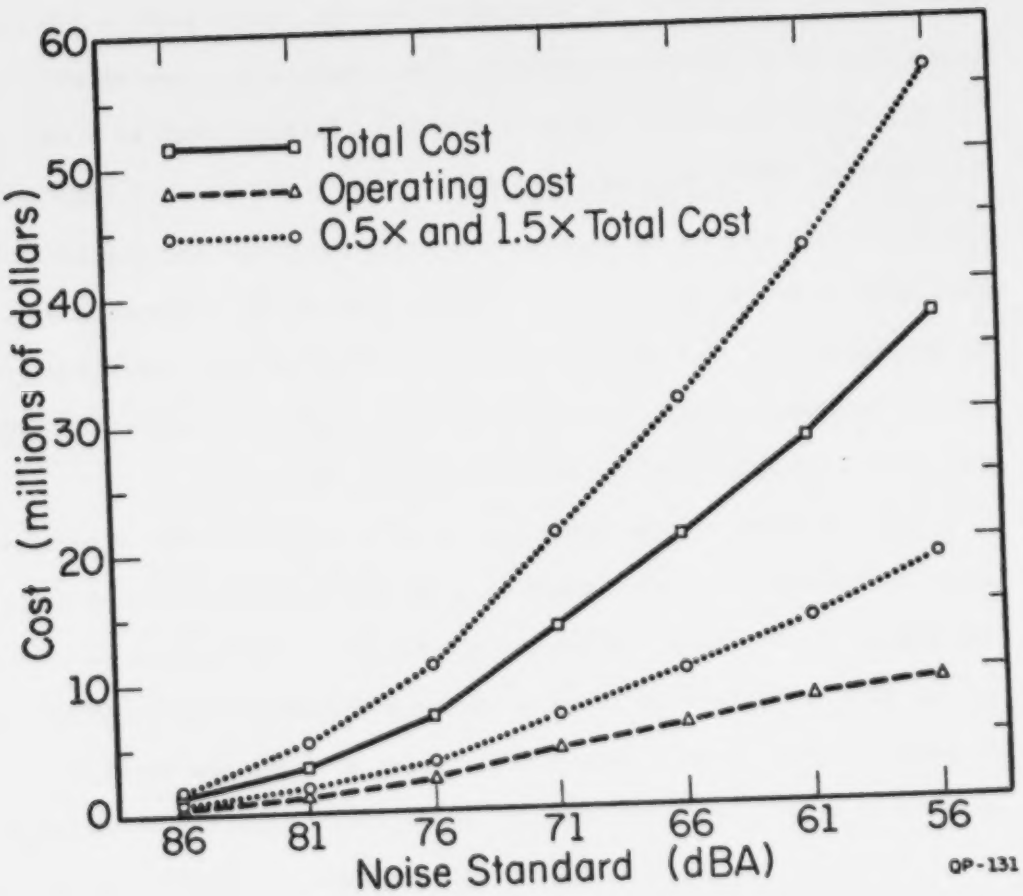
Regulatory Standard dB(A)	Operating Cost (in millions)
56	$9.98
61	8.15
66	6.24
71	4.37
76	2.41
81	1.04
86	0.43

Source: See text.

*Operating costs cover fuel costs and maintenance of the ventilating system. The costs are taken over 30 years and discounted at 10 percent.

and now represent 0.5 and 1.5 times Total Cost.

The I.E.P.A. capital cost estimates cited above in Section D can be adjusted to a total cost basis by assuming the same ratio of operating to capital costs as occurs for the basic statewide estimates (Tables 5 and 3). The resulting I.E.P.A. figures are about 41% of the basic statewide estimates at the 61 and 66 dB(A) levels and somewhat lower at higher noise standard levels (37% at 86 dB(A)). Thus, in Figure 2, the I.E.P.A. estimates would lie below the lower dotted line showing 0.5 x Total Cost.



OPERATING AND TOTAL COSTS TO MEET ALTERNATIVE NOISE STANDARDS

Figure 2

F. Procedural Costs

The parties to the hearings on noise standards for the forging industry are agreed that supercession of the present 56 dB(A) standard by a new one, whether it be 61 or 66 dB(A), will still leave a substantial number of forge plants in a state of non-compliance. Specifically, the EPA-MTU measurements, reproduced in Table 1, indicate that 22 plants would be unable to comply with 61 dB(A) and 18 with 66 dB(A). For these plants variances will have to be sought, or alternatively special standards will have to be devised. In either case, plants will presumably have to develop plans for eventually bringing themselves into compliance, and in the intervening years, for achieving that degree of noise reduction that is technically feasible and economically reasonable.

In these circumstances the question arises whether plants may incur procedural costs that would significantly add to the total costs of any regulatory standard. Under the EPA Proposal, for example, a non-complying firm would have to obtain a variance through a hearing before the Pollution Control Board. As a condition for securing the variance, it presumably would have to present the Board with a plan for noise reduction. Since the Board apparently cannot grant permanent variances,[1] the firm

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[1] This appears to be the implication of the recent decision of the Illinois Supreme Court in Monsanto v. PCB (Docket No. 48748, Agenda 35, March 1977). The court here observed (p. 4),

> "Monsanto suggests that the public health could be protected if the Board granted open-ended variances which could be reassessed when the Board became aware of new technology. This type of variance procedure, however, would not impel the development of such technology as does the present system of temporary variances. Moreover, Monsanto's recommendation for intermittent reassessment of indefinite variances has no statutory foundation."

would have to return for additional hearings at periodic intervals of perhaps 2-5 years to disclose such progress as it may have made in reducing noise emissions and to indicate what further steps it planned to take. It is conceivable that for many firms this process would continue for 15 or 20 years or more.

The FIA proposal is not based on the variance mechanism. Rather it would require that each plant not in compliance with a 66 dB(A) limit prepare and file with the Board a noise control plan specifying the most effective abatement methods available to it that are technically feasible and economically reasonable. The Board would then hold hearings, establish individual standards for each such plant, and determine a schedule for timely compliance.[1]

The procedural costs arising from this approach are at some points difficult to appraise. The hearings, which would be separate for each regulation, represent one major element. These hearings might be somewhat more elaborate and time-consuming than a variance proceeding, though this is not clear. At later points in time, one or more additional hearings might be needed to monitor the progress of firms in meeting their abatement schedules or in response to requests for amending the regulations. But the likelihood and frequency of any such hearings is

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[1] A variation on this approach, though not one suggested by either the FIA or the EPA, would be to classify non-complying plants into groups on the basis of one or more relevant characteristics, and then to establish a set of standards for each of the groups. With this approach, and presuming the possibility of grouping plants in a logical way, fewer separate standards or regulations would be needed. One simple basis of grouping, for example, would be the present level of noise emissions from plants. Table 2 above classifies plants in this way.

uncertain. In addition, it is possible, though again not certain, that economic impact statements would be required for each instance of a separate regulation. It is reasonable to suppose, however, that an economic impact statement dealing with an individual plant would be easier and less costly to prepare than a statement covering the entire industry.

It is fortunately the case that, given the overall context of this study, a careful and detailed assessment of procedural costs is not necessary. A rough calculation of these costs as they would arise from the EPA's approach indicates that, though by no means negligible in absolute terms, they would be quite small relative to the costs of structural modification--in present value terms, running perhaps 1-2 percent of the latter for the 61 and 66 dB(A) limits. The corresponding costs under the FIA proposal would be in the same range or perhaps somewhat lower. Hence the failure to allow explicitly for these costs will not materially affect the outcome of our analysis.

An indirect cost of potential significance arises from an arrangement like that proposed by the EPA, and to a lesser extent by the FIA, and deserves mention at this point. When a firm must seek from the PCB the periodic renewal of a variance, and in so doing demonstrate the sufficiency of recent progress in abatement or, alternatively, the sufficiency of technical and economic obstacles in preventing progress, a new element of uncertainty is added to its economic decision process. The firm cannot know in advance that its justifications will be considered adequate and that its request will be approved. No matter how compelling it may have found technical and economic obstacles to be, it cannot be

sure that the Board will share its view. It thus must reckon more or less continuously with the possibility that it will be obliged to incur large additional outlays as a condition of continuing to operate, or that it may even have to cease operations. This circumstance adds risk to its economic position and is bound to color its economic decisions. As a reaction to the added risk, it will factor a risk premium into any decisions to expand output, renew its plant or build additional facilities. In consequence, the prospective returns from these actions will have to be greater than they otherwise would be. The net effect will be a reduction in the number and scope of initiatives of these kinds, and the industry can be expected to grow less rapidly than would it otherwise. This outcome, it may be emphasized, results from the uncertainty associated with the procedures in question, not from any known costs of compliance which constitute a separate element in the firm's situation.

While the direction of the effects from this kind of uncertainty is clear enough, the strength of these effects is difficult to predict. It could be expected to vary among firms, since each is somewhat differently situated. The main determining factors would be the size of the contingent financial burden faced by the firm and the characteristics it perceives of the decisions by regulatory bodies, especially as regards their predictability over time, the reasonableness of the environmental objectives they seek, and the recognition they give to the costs of attaining those objectives.

G. The Costs of a 6 dB(A) Reduction

In the Hearings of May 3, 1977, Robert Hellweg of the IEPA discussed recent German research and experience in quieting impact forging operations. He indicated that after application of technically feasible and economically reasonable control techniques to existing Illinois plants, 17 of them would remain in excess of the 61 dB(A) limit.

> "I obtained that estimate based on the West German experience of modifying existing forging plants to reduce the noise emissions. They found that generally existing plants can reduce the noise emissions no more than 6 dB(A)."[1]

The question was subsequently asked,

> "So that roughly 17 of the 45 plants in Illinois will not be able to afford to meet the regulation that the Agency proposes be adopted?"

The response was,

> "That is correct. I would also estimate that there would be 14 that could not meet the industry's proposal of 66. . ."[2]

If the maximum potential for noise reduction is indeed 6 dB(A), then no single standard, such as 61 or 66 dB(A), would be suitable for all shops. Rather a variable standard, setting different levels for differently situated shops, would be appropriate. Such an arrangement might, of course, be achieved through the FIA proposal, or through the

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[1] Hearings, p. 1301.

[2] Hearings, p. 1301. See also Exhibit 21, p. 10.

Agency's proposal coupled to the use of variances. In the latter instance, something in the nature of permanent variances would be called for, unless over time the conditions of technical feasibility or economic reasonableness changed.

In light of the reported German experience and Mr. Hellweg's expressed view, it is of interest to estimate the statewide costs of quieting all 34 non-complying shops by 6 dB. Mr. Pirn, in BBN #3400, developed estimates of capital costs covering all 55 Illinois forge shops for achieving successively 5, 10, 15 dB, etc., of noise reduction.[1] His figures can be roughly adopted to our purpose by multiplying each of them by the fraction 34/55, denoting the ratio of shops presently not in compliance to all shops. Carrying out this calculation gives the figures in the first column of Table 6. To these figures must be added the present value of estimated operating costs (covering energy consumption and annual maintenance for ventilating equipment), which can be calculated in a manner previously described (but this time covering all 34 shops for each degree of quieting). These costs are shown in the second column of the table, while the final column gives the total of capital and operating costs. The figures in the final column are in turn shown in Figure 3. The bands lying above and below the solid descriptor line, respectively representing .5 times and 1.5 times the base values, are,

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[1] Pp. 74-76.

Table 6

Capital and Operating Costs to Reduce Noise Levels by the Indicated Amounts, 34 Forge Shops

(Figures in millions of dollars, reduced to present value*)

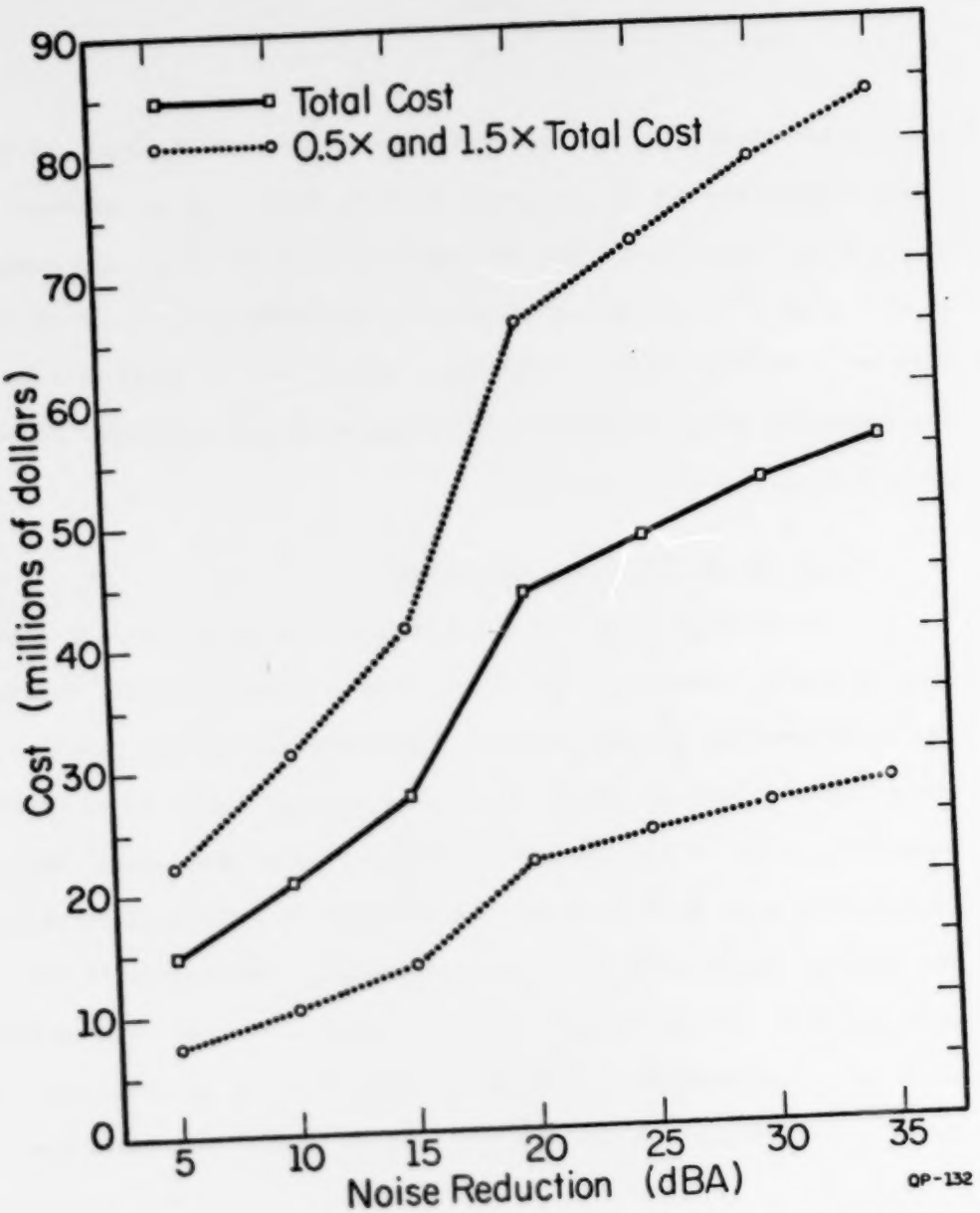
dB Reduction	(1) Capital costs	(2) Operating costs*	(3) Total costs
5	$10.03	$ 4.90	$14.93
10	13.91	6.92	20.83
15	18.61	8.91	27.52
20	32.71	11.27	43.98
25	36.21	12.06	48.27
30	40.33	12.31	52.64
35	43.60	12.31	55.91

Sources: Developed from data provided in BBN, #3400, pp. 74-76 and Holabird and Root, p. 4.

*Annual costs extended over 30 years and discounted at 10%.

as before, intended for reference purposes. They can be thought of as accommodating possible errors and alternate assumptions, though their proper location for this purpose is necessarily rather speculative.

The cost of a 6 dB noise reduction was not estimated directly, but it can be approximated through interpolation from Figure 3. An esti-



ESTIMATED TOTAL COSTS TO REDUCE NOISE LEVELS
BY VARIOUS AMOUNTS

Figure 3

mate of $16.11 million results. This sum covers all 34 shops, or 26 plants, currently not in compliance with 56 dB(A). If we consider instead only those plants not in compliance with 61 dB(A), the number of such plants[1] would fall to 22 and the estimated cost of a 6 dB reduction would decline to $13.62 million. Moving to a 66 dB(A) standard, the number of shops covered would decline to 18 and the statewide estimate would fall to $11.15 million.

H. Estimates for 10 Plants (12 Shops)

In the generalized BBN model that serves as a basis for statewide estimates, samples of individual cases provide essential inputs in the development of various estimating parameters. But the detail of those cases is lost in the process. Some of this detail is restored, however, in Section H of the BBN study referred to previously[2] and used for Table 3, which examines the costs of 10 individual forge shops. The approach taken in Section H is not entirely independent of the statewide approach. In particular, the unit costs associated with various noise reduction techniques are carried over from the general model, and these noise reduction techniques are applied to the individual cases

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[1] For consistency with the corresponding benefit figures developed later, the adjustment must be made on a plant, rather than shop, basis.

[2] See above, p. 10.

in a relatively gross, rather than precisely tailored, way.[1] At the same time, the cases are treated individually with respect to the number of elevations exposed and requiring treatment, the area of each elevation, and its suitability with regard to the alternative quieting techniques available. Hence an examination of this 10-plant group offers a basis for cost (and benefit) analysis that serves to complement the statewide estimates.

The results of this case-by-case examination are summarized in Table 7. The figures show, in present value terms for each of 10 plants, the combined capital and operating costs of reducing noise emissions by successive 5 dB increments. The underlying capital cost figures were taken from BBN 3400. The underlying operating cost figures were developed by the author in the manner described in the footnote to the table. They are essentially standardized, rather than being based on the unique characteristics of each plant. The maximum amount of noise reduction shown for each plant is determined by the amount of quieting needed to meet a 56 dB(A) standard on Class A land.

Table 8 is derived from Table 7 and shows the total cost for the 10 plants of meeting alternative noise standards. These estimates are also plotted in Figure 4 and connected by a solid line. They are accompanied by two other sets of estimates, both taken from the ETA

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[1] Expressed differently, the quieting methodology and the cost applicable in a given case are determined by analogy to the general model, not by case-specific engineering analysis.

Table 7

Combined Capital and Operating Costs of Achieving Specified dB(A) Reductions for 10 Individual Plants (12 Shops)

(Figures are in thousands)

dB(A) Reduction	Rockford Drop Forge	Forgings and Stampings	Moline Forge	DeKalb Forge	Cornell Forge	Armstrong Brothers Tool	Modern Drop Forge #	Amforge #	Wyman-Gordon, Harvey	Atlas Forgings
5	$ 464	$ 295	$ 403	$211	$231	$328	$ 531	$ 424	$ 674	$232
10	730	398	547	290	*	435	717	626	905	317
15	1,060	492	664	*		714	972	809	1,002	375
20	*	631	1,007			*	1,231	1,301	1,487	610
25		718	*				*	*	1,715	661
30		981							*	720
35		1,047								*

Source: Capital costs from BBN 3400, pp. 85-100. Operating costs are based on average per plant statewide figures, which range from $15,000 per annum for a 5 dB reduction to $38,000 per annum for a 35 dB reduction. Operating cost figures are adjusted for the smaller average size of plant in the 10 plant sample as compared with the statewide model. They are expressed in present value terms, using a 30 year period and a 10% discount rate.

Figures cover 2 shops.

* Further reductions not needed to meet the 56 dB(A) standard.

Table 8

Total Cost for 10 Plants (12 Shops)
of Achieving Alternative
Noise Standards

(Figures in millions)

Noise Standard	Total cost, 10 Plants*
56 dB(A)	$9.32
61	6.95
66	5.01
71	3.27
76	1.48
81	0.63
86	0.29

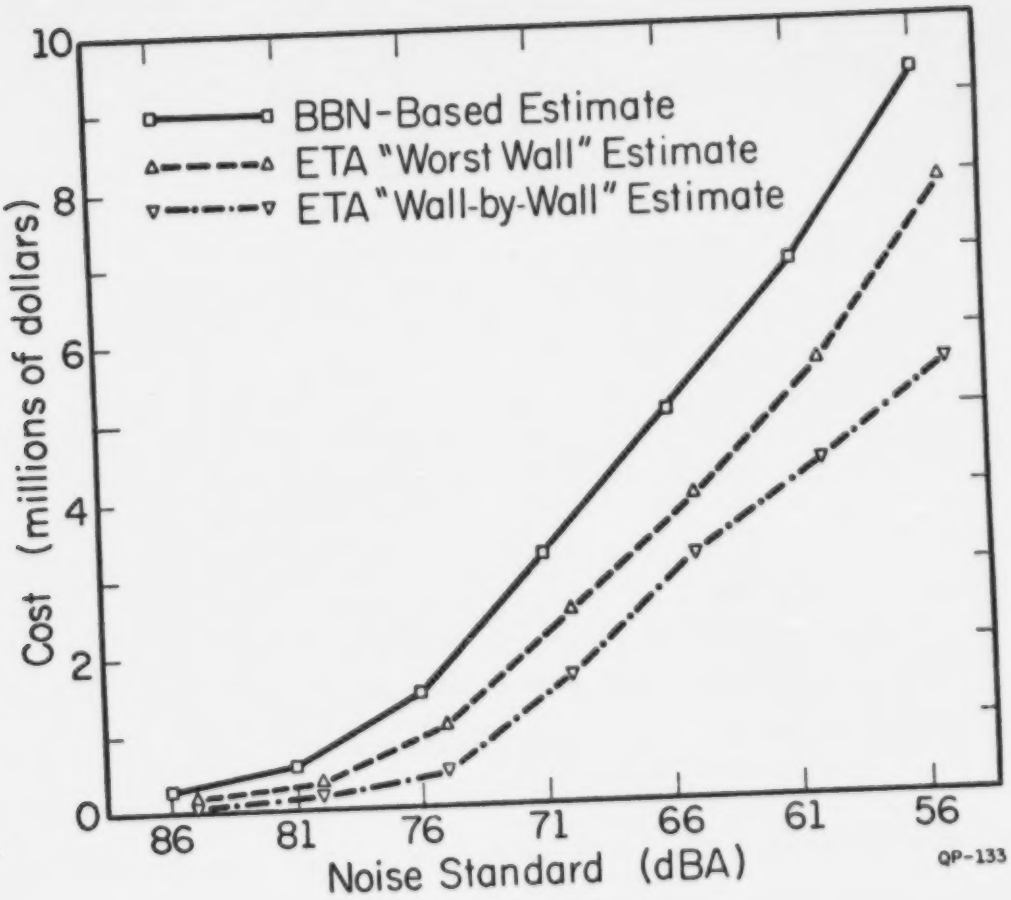
Source: Derived from Table 7.

*Figures cover both capital and operating costs.

Engineering Report.[1] The first, shown by the dashed line, is described by the authors as based on the "worst wall" assumption.

> "The control measures necessary to meet the maximum allowable sound level for the 'worst wall' of each plant are applied to all sides of the

[1] The Economic Impact of Impulsive Noise Standards on the Illinois Forging Industry, ETA, Inc., Oakbrook, Illinois, April 24, 1977. (Hereafter referred to as the ETA Report.) See Figure 4, p. 10.



TOTAL COSTS FOR TEN PLANTS TO MEET ALTERNATIVE NOISE STANDARDS

Figure 4

> plant. The 'worst wall' is defined as the wall facing the adjacent housing in the highest decibel range."[1]

The second set of estimates, shown by the dash-dot line, is based on the "wall-by-wall" assumption. In this case,

> "Controls defined as 'just sufficient' to satisfy the maximum allowable sound level are applied to each wall of each plant depending on the existing sound levels at housing facing each wall."[2]

The three sets of estimates differ significantly. For example, for the 65-66 dB(A) standard, the worst wall assumption yields costs about 4/5th's as great as those of the BBN study, while the wall-by-wall approach gives costs about 3/5th's as great. A part of the difference between the BBN estimates (with operating costs added by the present writer) and the worst wall estimates arises from the higher operating cost component of the former. The two cases use different "rules of thumb" to estimate annual operating costs, and these costs are extended over only 15 years in the ETA case. The remainder of the disparity is associated with differences between the BBN and ETA approaches in the criteria used to determine when a wall is exposed to residences and in need of correction and in the amount of correction required.[3]

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[1] ETA Report, p. 5.

[2] ETA Report, p. 5.

[3] For a discussion of the differences between the two approaches, see the ETA Report, p. 7 and Appendix I. The ETA estimates share with the BBN-based estimates many of the same data inputs and assumptions, as generated by Holabird and Root and by BBN. Hence they should not be thought of as a separate, independently-based set of figures.

The estimates in Table 8, along with the statewide estimates, will be used later in assessing the relation between the costs and the benefits of noise control.

I. The Burden of Compliance

A way of judging the burden on the industry that statewide compliance costs would impose is to compare them with industry sales revenues and payroll costs. For this purpose, we may use the U. S. Census of Manufacturers data presented earlier,[1] bearing in mind that there are some uncertainties about these data and they are subject to error. Table 9 summarizes the relevant information for the 56, 61 and 66 dB(A) standards. In column 1 statewide compliance costs, covering both the capital and operating components, are shown on an annual basis, assuming alternately that the capital portion is amortized over five and ten year periods. Sales revenues and payroll costs, having been adjusted to cover only the 26 non-complying plants and updated to 1976, are given in columns 2 and 3, while columns 4 and 5 show the respective fractions of these costs represented by compliance costs.

Compliance costs as a percent of sales indicate the ultimate potential for higher prices stemming from noise reduction requirements. Relatively, they indicate the size of the competitive disadvantage these 26 firms face vis a vis the remaining firms in Illinois already in compliance and firms out of state. From these vantage points the figures in Table 9 are not negligible. Moreover, the five year amortization period, which carries the higher figures, is perhaps more realistic

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[1] See p. 4.

Table 9

A Comparison of Annual Compliance Costs with Sales Revenues and Payroll Costs for 26 Plants

Standard	(1) Compliance Costs ($ millions)	(2) Sales Revenues ($ millions)	(3) Payroll Costs ($ millions)	Compliance Costs as a percent of (4) Sales	(5) Payroll
		5 year amortization			
56 dB(A)	$8.5	$181.2	$50.3	4.7	16.9
61	6.2	181.2	50.3	3.4	12.3
66	4.6	181.2	50.3	2.5	9.1
		10 year amortization			
56	5.7	181.2	50.3	3.1	11.3
61	4.2	181.2	50.3	2.3	8.3
66	3.1	181.2	50.3	1.7	6.2

Sources: See text. All figures relate to the group of 26 plants not in compliance with 56 dB. The sales and payroll figures have been updated from 1972 to 1976 by multiplying them by the ratio of money GNP in the later year to that in the earlier year.

for capital outlays which, from the firm's point of view, are non-productive, i.e., do not enhance the flow of net revenues. We may also consider compliance costs in terms of their prospective impact on forging company profits, assuming that the costs cannot be passed through. Data on such profits are not available, but discussion with industry sources suggests that for recent years, before taxes, they might run about 8% of sales. These figures may be compared directly with the sales percentage figures in column (4). Thus, compliance costs amounting to 4.7% of sales would reduce before-tax profits by about 59%.

Compliance costs as a percent of payroll give an idea of how these costs compare with wage and salary adjustments of familiar amounts. Alternatively, they indicate the magnitude of a payroll tax that would be the equivalent of compliance costs. Since payroll costs comprise only a third to a fourth of all costs, or sales revenues, in forging, the payroll percentage figures are substantially higher than the sales percentage figures. They suggest burdens equivalent to those ranging from moderate to quite large wage increases.

Included among data on the industry prepared by the Forging Industry Association are figures on Illinois payrolls and shipments larger than those given in the Census.[1] The use of these figures would reduce the percentage figures in Table 9 by about one-sixth.

The percentages in columns 4 and 5 would also be reduced appreciably if the Census sales and payroll figures were extended to cover all 45 Illinois forge plants rather than only those not in compliance. With this extension, the cost burden must be understood as applying to the entire Illinois forging industry instead of that segment of it not in compliance. It is worth bearing in mind that because plants are diversely situated with respect to their existing noise emission levels, the burdens of noise reduction will be unevenly shared among them.

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[1] See above, p. 5.

In testimony at the Hearings of February 16, 1977, the president of Moline Forge, Thomas Getz, provided information on sales, employment and other characteristics of his firm.[1] Moline Forge also was one of the 10 firms for which BBN prepared individual cost analyses in its Report #3400.[2] Combining the sales and payroll data provided by Mr. Getz[3] with the BBN cost data permits estimates to be made for Moline Forge of the same kind as are given on a statewide basis in columns 4 and 5 of Table 9. Compliance costs as a percent of sales turn out to be quite close to the statewide estimates. For 56 dB(A) and 66 dB(A), with 5 year amortization, they are, respectively, 4.6% and 2.5%. With payroll costs as the base, the respective figures are 16% and 8.7%. With 10 year amortization, the figures also are quite close to those in Table 9.[4]

J. Effects on Industry Growth and Employment

An increase in costs that affects some firms in an industry but not others tends to impair the competitive position of the first group. The compliance costs associated with the implementation of an impulsive noise standard would have this differential effect. Illinois

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[1] Testimony of Thomas Getz, Hearings, pp. 968-79.

[2] See pp. 88-89.

[3] Sales revenues were reported as $5 million for 1976. Payroll data were not given, but Mr. Getz has indicated to the author that payroll costs per employee are about $16,000. Multiplying this figure by the employment figure of 90 gives total payroll costs of $1.44 million.

[4] In his testimony, Mr. Getz offered estimates of compliance costs, described by him as rough and preliminary, that are substantially below the BBN estimates for Moline Forge. If these cost figures were used in place of the BBN figures, compliance costs as a percent of sales and payrolls would be reduced to between 55% and 70% of those given in the text.

forging firms compete with similar firms elsewhere in the country, especially with those in the nearby states of Wisconsin, Michigan, Indiana and Ohio. The ETA Report shows, for a sample of 16 Illinois firms, that out-of-state shipments were between 66 and 100% for 8 of them, between 33 and 66% for 3 of them, and less than 33% for 5 of them. Correlatively, although data are lacking on the point, we may expect that firms in nearby states ship significant fractions of their output into Illinois.

In these circumstances, Illinois firms will find themselves carrying environmental costs not borne by others. To the extent that they increase prices, they will face some loss of market share. To the extent that they do not, they will have to absorb the costs, thereby becoming less profitable. Either of these outcomes must have contractionary effects on output and employment in the Illinois segment of the industry. In the case of higher prices, these effects will be felt directly as, over time, buyers turn to cheaper sources. In the case of cost absorption and lower profitability, one might expect the effects to take place over a longer period of time. The more marginal firms might be led to terminate operations. Others would be disposed to avoid renewal and replacement expenditures or, if they had contemplated expansion, would be moved to undertake it out of state. In the end, both cases would lead to a smaller Illinois forging industry, with reduced output, revenues and employment.

There is nothing unique about noise abatement costs in generating these tendencies. Any cost increase that acts differentially

against Illinois firms will produce the same results. Thus, increases in employer taxes arising out of higher workmen's compensation benefits in Illinois or higher unemployment benefits also will exert constrictive effects on Illinois firms. A more important question in the present instance is whether the cost and potential price effects arising from the establishment of noise standards are large enough to be of concern.

Previously, in Table 9, an effort was made to assess the burden of alternative standards by comparing the cost of attaining them with both sales revenues and payroll costs. The revenue burden ranged from 1.7 to 4.7% and the payroll burden from 6.2 to 16.9%. These figures are, as was observed, large enough to merit notice. Even figures half as great, such as could occur if compliance costs turned out to be lower than calculated or payrolls and revenues higher than reported, would remain significant. Unfortunately, such figures do not in themselves tell us what consequences to expect for income and employment in the state. Some firms may be strong enough to absorb the cost increases without losing market share or retrenching in any way. Others may be sufficiently specialized in their product lines and so insulated from competition to be able to pass on the cost increases, at least in part. Still others may discover compensatory economies that help to offset the cost increases. But the presence of such possibilities cannot be taken for granted. Other things being equal, adverse competitive effects are to be expected. There is the contingency therefore that over time some

facilities that would have been expanded may not be, some that would have been newly built may be built elsewhere, some may move to other states, and some may terminate operations.

With the state of information and uncertainties being what they are, we cannot do more than identify these possibilities. We cannot predict on what scale they might materialize. We can say, conditionally, that each 1% by which the Illinois forging industry shrinks, or fails to grow, whether because of noise regulations or some other circumstance, would entail a direct loss of perhaps 55 jobs and $3 million in revenues, using data from the Census of Manufactures. Basing the calculations on FIA data, the corresponding figures would run 15% to 20% higher. Besides such direct effects, there would be indirect effects, bringing the total impact to perhaps 2.0 to 3.0 times the figures just noted.

The Forging Industry Association has indicated that (local) noise regulations were a major factor in the transfer of operations, or expansion outside of Illinois of Atlas Forgings Company (now Scot Forge) to Clinton, Wisconsin and of Klein Tools, Inc. (to Moran, Kansas).[1] According to testimony given in the Hearings,[2] the prospect of noise regulations was an important element in the decision of Moline Forge to purchase land in Iowa that could serve as an alternate site for its opera-

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[1] Letter of December 9, 1977, from FIA to the author.

[2] February 16, 1977, pp. 975-79.

tions. In the same testimony, the noise situation was also cited as a factor in the purchase by Modern Drop Forge of a new plant site outside of Illinois and in the search by Rockford Drop Forge for a plant site west of the Mississippi.

K. Effects on Illinois State and Local Government and on Agriculture

The implementation of noise standards for the forging industry, whether at 56 dB(A) or some higher level, is not expected to generate significant costs for Illinois governments or agriculture. The reason is that forgings are a relatively small component in the values of items that these entities purchase. To illustrate, most government outlays are for services or constitute transfer payments. With respect to the purchase of goods, the product group where forgings are of greatest importance would be motor vehicles. A solid measure of this importance is lacking, but we might tentatively take forgings to represent 1% of the value of an average motor vehicle.[1] Referring to Table 9, column (4), let us assume that compliance costs comprise 3% of the sales of the Illinois forging industry and that the prices of forgings would, as a result of noise regulations, rise by an equivalent percentage. Then the increase in the cost of an average motor vehicle would be the product of 0.03 and 0.01, or 0.03%.

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[1] Data provided the author by the FIA indicate, for example, that forgings might represent as much as 2.75% of the value of an average passenger car or as little as 0.3%. Mr. James Bullock of Wyman-Gordon suggests that a $25,000 truck might contain $250 worth of forgings.

The number of motor vehicles purchased annually by the State may be estimated at about 2100.[1] Taking the weighted average price of a vehicle to be $7000, total annual expenditures for cars and trucks would be $14.7 million, and .03% of this sum is $4400. That is, this sum would be the increased cost to the State arising indirectly from the increase in the cost of forgings.

Local governments collectively operate a considerably greater number of motor vehicles than state government. Applying a corresponding methodology, the number of vehicles purchased annually may be estimated at 7500 and the resulting increase in cost at about $16,000.

To the extent that the imposition of noise standards cause the forging industry to shrink or expand more slowly than otherwise, state and local governments will lose income. Each 1% or $3 million loss in revenues by Illinois forging firms, for example, might be expected to reduce the State's income tax take by, say, $12,000.[2] There would also be a property tax loss to local governments from the associated asset shrinkage. This tax is levied at a rate of about 1.5% on the market value of property. Data on the value of such property in forging are not available, but we might for illustrative purposes take it to be equal to the value of sales. In this case, a

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[1] According to data from the Secretary of States Office, the State operated 10,500 motor vehicles--8000 cars and 25000 trucks--in 1976. Assuming a five year useful life, "equivalent" annual purchases might be put at 2100.

[2] A $3 million revenue loss might in turn involve a $300,000 profit loss and the loss in tax would be 4% of this amount.

1% or $3 million reduction in sales implies an equivalent long term reduction in the value of property and a $45,000 loss in property tax revenues. Over the long run, however, it would be reasonable to expect a significant part of this loss to be offset by a reduction in the cost of services the State supplies to industry.

The use of forgings in agriculture occurs largely in connection with the farm machinery, trucks and agricultural vehicles on farms. About 165,000 trucks were used on Illinois farms in 1976 and, on the 5 year assumption, the net annual purchase of trucks may be estimated at 33,000.[1] In the same year, Illinois farmers owned about 485,000 other agricultural vehicles of various kinds[2] and annual net purchases might be put at 97,000. Valuing trucks at an average of $7,000 and other vehicles at an average of $10,000 gives a combined total for annual purchases of $1.2 billion, and multiplying this sum by .03% gives $360,000. This sum, which is subject to the assumptions previously noted, should be regarded as a very rough, illustrative, estimate of the additional costs to Illinois agriculture from price rises following upon increased forging costs.

The above analysis, both with respect to the impact on government and on agriculture, rests on the assumption that an increase in

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[1] Data from the Office of the Secretary of State. The bulk of these trucks are under 8000 pounds.

[2] This figure is developed from data in the Statistical Abstract of the United States: 1976 (U. S. Department of Commerce, pp. 653-4, Tables 1106, 1107).

costs to Illinois forging firms will be fully reflected in higher prices for the products used by these sectors. Since these firms compete with firms out of state, they may have difficulty passing on higher costs. To the extent that this is so, price increases to the final buyers of products containing forgings, including agricultural buyers, will be less than has been suggested.

III. BENEFITS FROM LIMITING NOISE AND COMPARISONS WITH COSTS

A. Ways of Evaluating Benefits

There are two main vantage points from which to assess the damage caused by noise or, alternatively, the benefits that would accrue from the abatement of that damage. The first is directed toward the physical effects of noise--interference with speech and sleep, annoyance and hearing damage. The second involves the measurement of the damage in dollar terms, without particular concern as to its physical form. The first of these approaches, useful as it is, does not permit a quantitative comparison of benefits with costs. For this reason, and because it has been covered extensively in the literature,[1] it will be given only brief comment below. The second approach will be relied on here and will provide the essential basis for damage evaluation and benefit analysis.

For present purposes, the following physical effects of noise may be noted:

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[1] Among the relevant sources are the following: Miller, J. D., "Effects of Noise on People," U. S. Environmental Protection Agency, NTID 300.7, December 31, 1971; "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," U. S. Environmental Protection Agency 500/9-74-004, March, 1974; Kryter, K. D., Effects of Noise on Man, Academic Press, New York, 1970; Noise as a Public Health Hazard, The American Speech and Hearing Association, ASHA Report 4, Washington, February, 1969; "Public Health and Welfare Criteria for Noise," U. S. Environmental Protection Agency 550/9-73-002, July 27, 1973; Thiessen, G. J., "Effects of Noise During Sleep," Physiological Effects of Noise, ed. D. L. Welch, pp. 271-75. A summary of much of this material, though one emphasizing motor vehicle noise, will be found in the document, Control of Noise from Motor Vehicles, Illinois Institute for Environmental Quality, No. 74-42, Part V.

1. Sound levels out of doors as low as 60 dB will require raised voices for effective communication if the participants are as little as 10-15 feet apart; indoors, with windows closed, sound levels of 75 dB will have the same effect. Higher noise levels require lesser distances or louder voices if communication is to remain satisfactory.

2. Indoor noise levels as low as 45-50 dB can disturb sleep, with the intensity of disturbance and the probability of awakening increasing as the noise level rises.

3. Unwanted noise at levels of 55 and 60 dB may be regarded by some subjects as annoying, with the likelihood and severity of annoyance rising, as before, as the noise level rises. Typically, only a fraction of those who are annoyed, or even highly annoyed, will complain, so that the number of complaints will understate the significance of the problem.

4. Degrees of permanent hearing loss may result from cumulative exposure to noise--8 hours daily over a prolonged period of time--even though the noise level might range no higher than perhaps 70 dB.[1]

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[1] A permanent threshold shift (PTS) in hearing from prolonged exposure to moderate noise levels often manifests itself as an intensification of ordinary hearing loss due to aging. There is disagreement as to the noise level at which this intensification begins to occur. J. C. Guignard, in A Basis for Limiting Noise Exposure for Hearing Conservation (Wright Patterson Air Force Base, Ohio, July, 1973), p. 25, suggests a 75 dB(A) threshold. In contrast, K. D. Kryter has proposed 55 dB(A) as a threshold in his paper, "Impairment to Hearing from Exposure to Noise". (J. of Acoustical Soc. of Am., V. 53, No. 5, May 1973, pp. 1211-1234). The U. S. Environmental Protection Agency has identified a continuous sound level limit of 75 dB(A) for eight hours daily exposure as requisite to protect public health and welfare with an adequate margin of safety.

The noise levels cited above at which the various adverse effects occur are well below those emitted (at the nearest residential property) by many forging plants, as indicated in Tables 1 and 2. Of the effects noted, the most significant would appear to be annoyance. Table 10 indicates that about 45% of all affected dwellings, or 3000 of them, are subject to noise levels of 60 dB or more. The residents of these dwellings would be disturbed primarily when out of doors, though a substantially smaller number would also be disturbed indoors. Interference with sleep ought not to be a large problem, at least not currently, since relatively few plants operate hammers during the night. Nor should hearing loss present a significant problem, though there may be some incidence of it from the cumulative effects of prolonged exposure. Suppose, for example (consistent with the preceding footnote) that the threshhold level for such effects to occur were 65 dB(A). To produce this level inside the home requires an outdoor noise level of about 80 dB(A). Data that are developed later (Table 10 below) indicate that there are approximately 21 dwellings statewide that experience forge noise levels of this magnitude or greater. The occupants of these dwellings who are home each day for most days of the week would, on these assumptions, after exposure over many years, experience a degree of hearing loss. One might expect, however, that the incidence of this effect would be tempered by the tendency of many people to change homes and neighborhoods after limited periods of time.

B. The Method of Quantitative Assessment

Although we are not able to express our preference for quiet, or reduced noise, by the direct, specific purchase of it in the marketplace, we do engage in certain transactions in which, implicitly, we place a value on it. An important type of such transaction is the purchase of a house. One's assessment of a particular dwelling depends on the many characteristics of that dwelling, including various features of the neighborhood in which it is located, and on the flow of benefits which those characteristics are perceived to bring. Among the characteristics in question are the style of house, its age, its size, number of bedrooms, whether it has air conditioning, proximity to schools, accessibility to downtown, noisiness of the neighborhood, whether the neighborhood is affected by air pollution, etc. Accordingly, we may think of these characteristics as the variables that determine the value of a house. To the extent that they are favorable, a dwelling will sell for more; to the extent that they are unfavorable, a house will sell for less. The relationship involved here may be written

$$V_o = f\ (Z_1, Z_2, Z_3, \ldots, Z_n)$$

where Z_1, Z_2, etc. = the characteristics that determine the dwelling's value,

and

V_o = dwelling value

Once decisions have been made as to the independent variables to include and the specific form of the relationship, and given a sufficient set of

observations on each of the variables, regression procedures will yield numerical estimates of the coefficients associated with each of the independent variables. The coefficients provide a measure of the influence of each variable on the dwelling price. The partial derivative of V_o with respect to an independent variable, e.g.,

$$\frac{\partial V_o}{\partial Z_1} = \frac{\partial f}{\partial Z_1} ,$$

in turn expresses the change in dwelling value arising from a small change in the independent variable. Thus if Z_1 is the average neighborhood noise level measured in dB(A), the derivative will tell us by how much a 1 dB(A) change in that level will affect the dwelling price. Differently, it will tell us the worth that a home-buyer attaches, on the average, to a 1 dB(A) reduction (or increase) in residential noise. The worth in this case represents a capitalized sum or present value of the expected flow of benefits to the buyer from a 1 dB(A) reduction that continues over an indefinitely long succession of future years.[1]

A handful of investigators have employed an econometric

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[1] The benefits to property owners from a noise reduction represent bona fide economic gains. But it does not follow from this that all existing owners previously suffered a loss from the earlier, higher noise level. Those who purchased their properties after the onset of that higher noise level would have obtained them at a discount because of noise damage. The discount may be understood as a (capitalized) compensation to such buyers for the noise damage they will suffer. The subsequent reduction in the noise level and increase in property values would thus, for these buyers, represent a windfall gain.

approach of this kind in order to estimate how individuals evaluate the effects of various types of pollution, including noise pollution. Their findings show variability but at the same time contain sufficient consensus to suggest the magnitude of benefits from noise reduction and to provide quantitative benchmarks for analytical purposes.[1] While these studies have been directed toward motor vehicle and aircraft noise as the more pervasive noise sources, their findings may be regarded as generally applicable to other sources of neighborhood noise of a continuing or frequently recurring kind.[2]

For purposes of the analysis that follows, two separate studies will be relied on, one by Jon P. Nelson, based on data for the Washington, D. C. SMSA, and the other by R. J. Vaughn and L. Huckins,[3] based on Chicago area traffic noise data. In seeking to determine the effect of noise (and other factors) on property values,

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[1]For a brief review of some of the literature, see Jon P. Nelson, The Effects of Mobile-Source Air and Noise Pollution on Residential Property Values, Department of Transportation (DOT-TST-75-76) April 1975, pp. 7-4 - 7-6.

[2] The estimation of pollution damages by reference to differential property values involves certain conceptual and procedural problems, and the results from this type of study must, at this stage, be regarded tentatively. For a discussion of some of the issues see, for example, Polinsky, A. M. and Shavell, Stephen, "The Air Pollution and Property Value Debate," Review of Economics and Statistics, Vol. LVII, 1975; also Freeman, A. M., "Air Pollution and Property Values: A Methodological Comment," Review of Economics and Statistics, Vol. LIII, p. 415, (1971); and Freeman, A. M., "On Estimating Air Pollution Control Benefits from Land Value," Journal of Environmental Economics and Management, Vol. 1, p. 74 (1974).

[3]Nelson, op. cit. Also, Roger J. Vaughn and Larry Huckins, "The Economics of Expressway Noise Pollution Abatement," RAND Corporation, Paper P-5475, August 1975. For a brief review of the literature in this area, see the Nelson study, pp. 7-4 to 7-6.

Nelson made use of a semi-logarithmic form of regression relationship. Vaughn and Huckins (hereafter V & H) also made use of this form of relationship in developing one of their basic sets of findings, while a simple linear relationship was employed in an alternate treatment of the problem. The semi-log form has the effect of making the damages from noise dependent not only on the noise level but also on the value of the affected property. This is the kind of relationship one would expect. That is, one would expect that the dollar damages from a given noise level would be greater for properties of greater value. More specifically, with the semi-log form, damages are a constant percentage of property value. By contrast, with a linear relationship, damages and the consequent dollar reduction in property value would be the same for an expensive property as for an inexpensive one. Because it is more reasonable to suppose that noise damages are property value dependent than the contrary, the semi-log relationship will be emphasized in the analysis that follows.

The basic relationship employed in the semi-log model is of the form,

$$(1) \quad \ln V_o = aN_o + bZ_1 + cZ_2 \ldots$$

where

V_o = the market value of a particular dwelling;

N_o = the value of an index that measures the noise level at this property;

$Z_1, Z_2 \ldots$ = measures of other characteristics of the property which, together with N_o, determine its value;

a, b, c, = numerical coefficients resulting from regression analysis

Consider now a second property with value V_1, identical in all respects to the property with value V_o, except that its noise index N_1 is lower and it thus suffers less noise damage. For this property, the corresponding equation is

$$(2) \quad \ln V_1 = aN_1 + bZ_1 + cZ_2 \ldots$$

Subtracting (1) from (2) gives

$$(3) \quad \ln V_1 - \ln V_0 = a(N_1 - N_0) ,$$

$$(4) \quad \ln\left(\frac{V_1}{V_0}\right) = a(N_1 - N_0) ,$$

$$(5) \quad \frac{V_1}{V_0} = e^{a(N_1 - N_0)} , \text{ and}$$

$$(6) \quad V_1 = V_0 e^{a(N_1 - N_0)}$$

The extra damage, D_0, to the noisier property may now be expressed as

$$(7) \quad D_0 = V_1 - V_0 = V_0 e^{a(N_1 - N_0)} - V_0 = V_0 \left[e^{a(N_1 - N_0)} - 1\right]$$

Equation (7) permits one to determine how the value of a noise-impacted property will change as the noise level is reduced. That is, it yields an estimate of the benefits to be gained from noise reduction.

The noise index, N, used by V & H is equivalent to an L_{eq} measure.[1] It employed 50 dB(A) as a cutoff, so that properties with

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[1] L_{eq} is defined as the level of a constant sound which, in a given situation and time period, has the same sound energy as does a time varying sound. Technically, L_{eq} is the level of the time-weighted mean square, A-weighted sound pressure.

noise levels of this amount or less were treated as free of noise damage. Thus a property with a 65 dB(A) noise level would benefit from noise reductions to a maximum of 15 dB(A). With this approach, the noise index N is equal to the observed noise level minus 50 dB(A). The authors found the cutoff to be supported by statistical analysis.[1]

In the Nelson study, the noise index $L_{10} - L_{90}$ was used, where L_{10} denotes the noise level exceeded 10% of the time and L_{90} the noise level exceeded 90% of the time. This index can be translated into an approximate L_{eq} measure.[2] In the present study, a 1 dB(A) change in the Nelson index will be treated as equivalent to a 1 dB(A) change in L_{eq}. The implications of a somewhat different numerical relationship between the two measures can be easily inferred.

Although his procedures differed from those of V & H, Nelson also, in effect, used a lower limit cutoff for benefits from noise reduction, which may be taken as approximately 50 dB(A). The noise index is therefore the same as for the V & H study.[3]

In equation (7) above, the regression coefficient "a" in the Nelson study was estimated to be -.0041. Identical results were

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[1] See V & H, p. 21.

[2] An examination of the relationship between the $L_{10} - L_{90}$ index and the L_{eq} measure will be found in the volume, Economic Impact Study of the Proposed Motor Vehicle (In Use) Noise Regulations, Report of the Task Force on Noise, IIEQ Document No. 76/10, May 1976, pp. 132-33.

[3] Background noise levels were assumed to be 40 dB(A) for quiet tracts, 50 dB(A) for normal tracts, and 60 dB(A) for noisy tracts. See the Nelson study, pp. 7-8 and 7-17.

obtained for one of the models in the V & H study. Accordingly, our base case in the estimation of benefits will rely on this figure.[1] A variant case also will be presented. To illustrate the application of the coefficient, if a residential property has a value V_0 of $15,000 at an existing noise level, N_0, of 70 dB(A), then a reduction in the noise level to 60 dB(A) will reduce the capitalized value of damages--with equivalent benefits--by $628.

The benefits that are measured in this way, or more generally by methods having reference to differential property values, cover all those benefits that the homeowner would perceive, or be aware of, in buying a home. Examples would be the benefits that a quieter environment provides from the lower levels of speech and sleep interference, from less disturbance to reading and concentration, and from less annoyance. On the other hand, any benefits from quieter surroundings of a more subtle kind, such as reduced hearing losses that might show themselves only over long periods of time, would not be likely to be perceived by homeowners and therefore would not be reflected in the prices of homes.

To use equation (7) above to estimate benefits from the reduction of forging noise, it is necessary to express the noise measure in terms of L_{eq}. Rule 206 governing impulsive noise calls for measurement using the A-weighted, fast meter mode, and the EPA/MTU measurements made at residential sites, summarized in Tables 1 and 2, are consistent with this requirement. In an analysis of impulsive noise from

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[1] See the Nelson study, p. 7-17, Table 7-6, and the V & H study, p. 89, Table C-4, Case C. The statistical finding of .0041 is somewhat weak in the latter study.

forge hammers prepared by John R. Shadley of BBN for the FIA,[1] the relationship, L_{eq} = A-weighted fast - 5 dB(A), is developed. (The relationship includes a 5 dB(A) penalty for impulsive noise.) The validity of the relationship, which depends in part on assumptions about the average frequency of hammer strikes, was subjected to extensive discussion in the Hearings.[2] At issue was whether the correction factor should be 5 dB(A) or a lesser amount. In the calculations below of benefits, this factor does not affect the amount of noise reduction needed to meet any specified limit, but it does affect the location of the 50 dB(A) cutoff limit. A smaller correction factor would lower the cutoff point and raise the benefit estimates.[3] However, if there is any bias toward underestimation from the use of the Shadley formula, it is probably fully, perhaps more than fully offset by an opposite bias. For many forge plants, a 50 dB(A) cutoff is too low. Ambient noise levels around these plants are sometimes 55 or 60 dB(A) or higher.[4] In these cases, benefits for households will be overestimated by the 50 dB(A) cutoff. Accordingly, use of the Shadley formula seems unlikely to cause an underestimation of benefits. It was used in the ETA Engineering Report and will be used also in the calculations below.

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[1] Forging Hammer Noise in the Community, BBN Report No. 3399, December 9, 1976.

[2] Discussion of the issue will be found in the Hearing Record for September 22 and December 13, 1976, and May 2 and 3, 1977. Also Exhibits 32, 67 and 68.

[3] For example, with a 5 dB(A) correction factor, a 50 dB(A) cutoff expressed in L_{eq} is equivalent to a 55 dB(A) cutoff expressed in the A weighted fast measure. With, say, only a 2 dB correction, the A weighted fast measure would be 52 dB(A).

[4] See the EPA-MTU Survey, which often reports the ambient noise levels for individual plants. The Survey is not conclusive on this point, however, since the recorded ambient is sometimes attributable to the non-hammer operations of a plant rather than non-forge sources.

C. Estimates of Statewide Benefits and Comparisons with Costs

To estimate the value of benefits statewide with the aid of equation (7), data are required on the value of homes around forge plants and their distribution by forging noise levels. These data are not available for all 26 non-complying plants, but ETA Engineering has developed them for the 10 plants referred to earlier in Section II H.[1]

To meet the needs of the present study, this sample of data has been used to build a statewide model for estimating benefits. The steps involved in this process were as follows:

1. The number of dwellings within each noise contour zone were summed over all 10 plants, to get a consolidated noise contour map.

2. The number of dwellings within each contour zone was scaled up from a 10-plant basis to a 26-plant basis by multiplying by 26/10.

3. The resulting number of dwellings in each contour zone was "distributed" equally among the forge plants with noise levels (at the nearest property) equal to or above the level of the zone. For example, the 237 houses in the 70-74 dB zone were assinged to the 13 forge plants with noise levels within or above this range so that, in effect, each plant was assigned 18.2 houses. Similarly, the 18 houses in the 80-84 dB zone were assigned to the 5 plants with noise levels

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[1] The data provided the basis for the 10-plant benefit estimates in the the ETA Report, pp. 15-16, and were made available for the present study.

within or above this range, for an average of 3.6 houses per plant. This procedure served to provide a distribution of houses by noise levels for each plant, in turn permitting a determination of the noise reduction (down to $L_{eq} = 50$) experienced by the houses at each level from a given noise reduction by the plant. Table 10 shows the essential information underlying the assignment procedure.

4. Using the information in Table 10, including the data on property values (V_0), equation (7) was applied to calculate, for the houses (also, separately, apartments and mobile homes) in each noise zone, for each plant, the value of benefits resulting from a given noise reduction by the plant.

5. Summing these benefits over the several noise zones and, in turn, multiplying by the number of similarly situated plants, e.g., all plants required to reduce their noise levels by 25 dB(A) in order to meet a 56 dB(A) standard, gave total benefits from the specified reduction for that group of plants. Repeating this procedure for other groups of plants required to reduce their noise level by different amounts to meet the same standard and then summing over all groups yielded a statewide estimate of the benefits to gained from meeting that standard.

The results of this procedure are summarized in Table 11, which shows benefits of $4.02 million accruing from a 56 dB(A) standard, $3.52 million from a 61 dB(A) standard, and $2.78 million from a 66 dB(A) standard. The estimates are shown also in Figure 5, along with the estimates of combined capital and operating costs (from Figure 2) to achieve

Table 10

Distribution of Dwelling Units by Noise Levels and Associated Number of Forge Plants (Statewide Figures)

dB(A) Level	Houses	Apartment Units	Mobile Homes	Number of Plants[1]
85-89	2.6	---	---	3
80-84	18.2	---	---	5
75-79	44.2	10.4	---	9
70-74	236.6	33.8	---	13
65-69	663.0	80.6	23.4	18
60-64	1682.2	122.2	91.0	22
55-59	2709.2	431.6	767.0	26
1976 Dwelling Value, V_0[2]	$27,872	$16,936	$11,800	

Source: Figures showing distribution of dwellings by noise level developed from data on 10 plants provided by ETA Engineering, Inc.

[1] Figures show the number of plants with noise levels equal to or higher than those indicated.

[2] Dwelling values for houses and apartments are weighted averages of figures supplied by ETA Engineering and based on 1970 U.S. Census of Housing data. The apartment figure has been converted from a monthly rental amount by applying a real estate rule-of-thumb and multiplying by 100. Both figures have been updated to 1976 using a housing price index from Construction Reports (U. S. Department of Commerce). The mobile home figure is a 1976 estimate by ETA Engineering.

Table 11

Base Case Estimates of Statewide Benefits from Meeting Alternative Noise Standards, 26 Plants

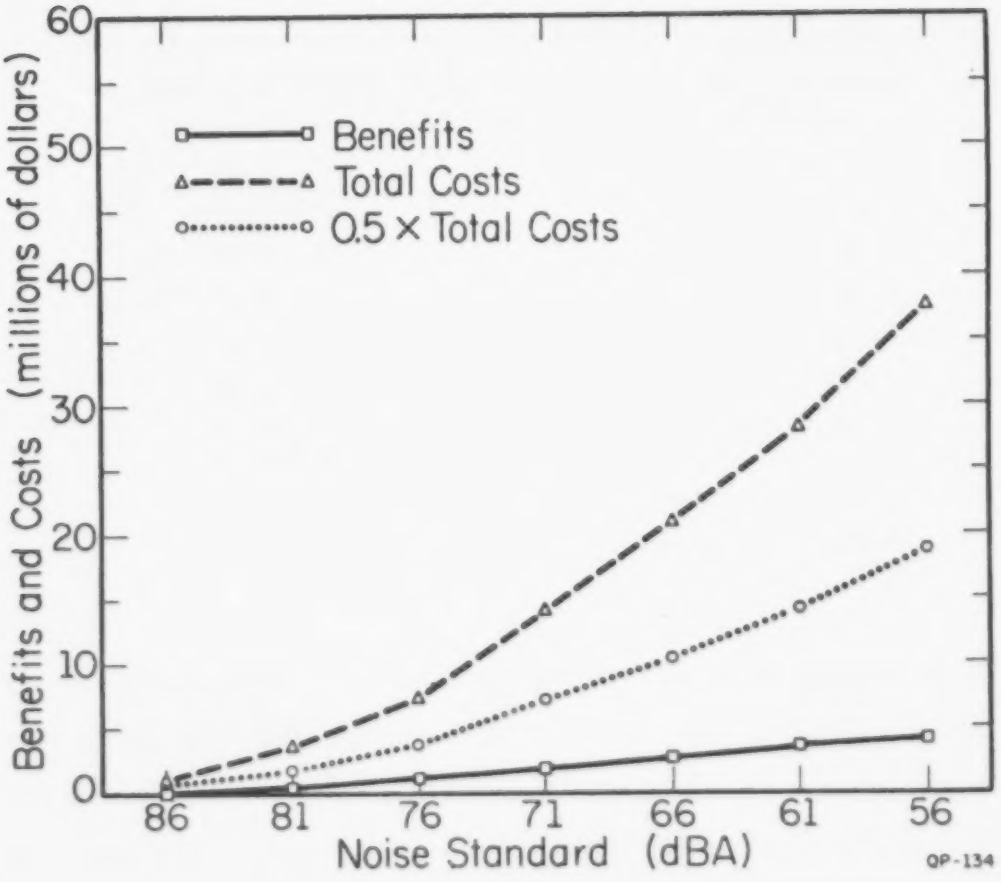
(Figures in millions)

Noise Standard	Total Benefits*
56 dB(A)	$4.02
61	3.52
66	2.78
71	1.92
76	1.14
81	0.46
86	0.10

Source: See text.

*Capitalized values.

the designated standards. Two points stand out. First, costs greatly exceed benefits at every noise standard, from 56 dB(A) through 86 dB(A). At the standards of particular interest, namely 56, 61 and 66 dB(A), the ratios of benefits to costs are, respectively, .10/1, .12/1, and .13/1. Second, as one moves from a lenient 86 dB(A) standard to progressively more restrictive ones, incremental costs remain consistently much in excess of incremental benefits. For example, moving from an 86 dB(A) standard to an 81 dB(A) standard would add $1.90 million to costs, but only $0.36 million to benefits; similarly, going from 66 dB(A) to 61 dB(A) would add $7.46 million to costs but only $0.74 million to benefits. These incremental costs and benefits are shown in columns 1 and 2 of Table 12.



ESTIMATED STATEWIDE BENEFITS AND COSTS FOR 26 PLANTS

Figure 5

Table 12

Statewide Incremental Benefits and Costs at Alternative Noise Levels, Base Case and Variant Case

(Figures in $ millions)

dB Interval	Base Case		Variant Case
	Δ Costs	Δ Benefits	Δ Costs
86 to 81	$1.90	$0.36	$0.95
81 to 76	4.19	0.68	2.09
76 to 71	6.78	0.78	3.39
71 to 66	6.79	0.86	3.39
66 to 61	7.46	0.74	3.73
61 to 56	9.72	0.50	4.86

Source: Tables 3, 5 and 11.

In order to test the strength of the foregoing findings, consider how the cost-benefit balance would be affected if costs were substantially lower, or benefits substantially higher, than those developed for the base case in Figure 5. In following this procedure, we deliberately ignore any circumstances that might work in the opposite direction, toward higher costs or lower benefits. Accordingly, suppose that costs were but 50% of the base estimates, as described by the dotted line in Figure 5. The benefit-cost ratios would then double, though they would still remain well below 1.0. Also, the gap between incremental benefits and costs would decline, but the benefits would continue to fall far short of the costs. The incremental values for this variant case are shown in the last two columns of Table 12.

In the V & H study, results are presented for two modified versions of their semi-log model.[1] From a statistical point of view, it is debatable whether either of these versions is preferable for our purposes to the one relied on above.[2] Perhaps more important, the consistency of the latter's results with those of the Nelson study add to one's confidence in it. But for purposes of further evaluation, let us consider the alternate version that, of all three, yields the highest measure of benefits. The relevant regression coefficient in this instance is -0.0069 and the resulting benefits are approximately 70% higher than those shown in Table 11 and Figure 5.

Table 13 shows these augmented benefit figures, along with cost figures equal to one-half those of the base case (as described by the 0.5X reference line in Figure 4). As before, costs remain appreciably in excess of benefits, with the former two to four times the latter. An examination of the incremental changes shows, again, costs in excess of benefits at each step, from 86 dB(A) down to 56 dB(A).

I.E.P.A. cost estimates, based on a smaller area for a typical forge shop elevation than was used in BBN 3400, were discussed earlier

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[1] See p. 89 of the Study, Cases A and B. Both of these versions, like the version previously discussed, employ an energy-based noise measure.

[2] The coefficients of determination are appreciably lower for the modified versions, but their coefficients for the noise variable show smaller standard errors.

Table 13

Alternate Estimates of Statewide Benefits and Costs from Meeting Alternative Noise Standards*

Noise Standard	Total Costs*	Total Benefits*
56 dB(A)	$19.04	$6.83
61	14.18	5.98
66	10.46	4.73
71	7.06	3.26
76	3.67	1.94
81	1.58	0.78
86	0.63	0.17

Source: See text.

*Costs are 0.5 times those of the base case.
Benefits are 1.7 times those of base case.

in Sections II D and E. The total cost figures resulting from these estimates are as follows:[1]

Noise Standard	Total Costs
61 dB(A)	11.73
66	8.65
71	5.45
76	2.73
81	1.42
86	0.46

[1] I.E.P.A. provided only capital cost estimates. They were adjusted to a total cost basis in the manner described in Section E.

These estimates are considerably lower than the corresponding cost estimates in Table 13 but still well above the augmented benefit figures in that table.

D. The Benefits and Costs from a 6 dB(A) Reduction

Section II G considered the view that, as a practical matter, it might not be possible to reduce the noise level at a given plant by more than 6 dB(A). The cost estimates pertinent to such a reduction are restated in Table 14 below, along with estimates of the corresponding benefits. As with the earlier comparisons, the costs are much in excess of the benefits for each of the indicated standards. The outcome is similar when one considers the incremental changes in moving from the 56 dB(A) standard, with 26 plants covered, to either of the higher standards, with fewer plants covered.[1]

E. A Comparison of Benefits and Costs for 10 Plants

In Section II H above, using BBN data, estimates were presented of the costs of quieting for 10 individual plants (Table 7). These same 10 plants comprised the group subjected to individual study by ETA Engineering, and for which that organization has provided, on a per plant basis, data on the distribution of dwellings by noise level.

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[1] The I.E.P.A., in comments on an initial draft of this study, has estimated the capital costs for a 5 dB(A) reduction at $3.96 million and for a 10 dB(A) reduction at $5.57 million. The estimates, based on the same per-square-foot-cost of quieting as the BBN-based estimates but using a smaller figure for the average area of a forge shop elevation, cover those plants with noise levels in excess of 61 dB(A). Adjusting these figures to allow for operating costs (on the basis of the operating cost-capital cost ratios indicated in Table 6 above) gives $5.89 million for a 5 dB(A) reduction and $8.34 million for a 10 dB(A) reduction. Interpolating linearly for a 6 dB(A) reduction gives $6.30 million. This figure may be compared with the benefit estimate, shown in the middle row of Table 14, of $2.62 million for a 6 dB(A) reduction.

Table 14

Comparison of Estimated Statewide Costs and Benefits from a Noise Reduction of 6 dB(A) Per Plant*

Noise Standard	Costs	Benefits
56 dB(A)	$16.11	$2.73
61	13.62	2.62
66	11.15	2.27

Source: See text.

*The figures for each standard cover only the plants not in compliance with that standard--26 plants for 56 dB(A), 22 for 61 dB(A), and 18 for 66 dB(A).

These data have been used in the present study to develop benefit estimates for the individual plants, by a procedure similar to that used for the statewide estimates but without scaling up or aggregating. That is, the essentials of the method are the same, but all of the data are plant specific.

The results are summarized in Table 15, along with corresponding cost data that have been adapted from Table 7.[1] The figures show for every plant, for every noise standard, a balance of costs over

[1]It was necessary to adjust the cost figures in Table 7 downward in most instances to put them on a comparable basis with benefits, since they show successive costs for full 5 dB(A) increments, whereas the requisite amount of reduction is generally in the interior of an interval, rather than on a boundary.

Table 15

Benefits and Costs Associated with Alternative Noise Standards for 10 Plants

(Figures in $ thousands)[1/]

Plant	Maximum Noise Standard in dB(A)						
	86	81	76	71	66	61	56
1. Rockford Drop				*	28	47	52
					278	584	919
2. Forgings and Stamp.	7	35	57	72	81	86	87
	59	239	361	505	603	850	927
3. Moline Forge			*	42	82	94	97
				242	438	575	906
4. DeKalb Forge					*	0	1
						42	174
5. Cornell Forge						*	0
							46
6. Armstrong Bros.				*	9	21	29
					197	348	619
7. Modern Drop			*	48	72	83	87
				319	574	842	1,108
8. Amforge			*	247	446	525	554
				254	501	608	1,171
9. Wyman-Gordon[2/]		*	222	420	482	496	500
			404	724	868	1,338	1,578
10. Atlas Forgings	56	84	96	103	107	109	111
	186	285	350	580	635	696	767
Totals Benefits	63	119	375	932	1,307	1,461	1,518
Costs	245	524	1,115	2,624	4,094	5,883	8,215

Source: See text.

[1/] Upper figures in each box are benefits; lower figures are costs.

[2/] Costs cover only one of four shops.

*Plant already complies with the indicated standard.

benefits. The balance is decisive for all plants except Amforge, Wyman-Gordon, and Atlas at the 86, 81, and 76 dB(A) levels. That is, except for these three plants, an increase in benefits of 70% and a halving of costs would not alter the outcome. In the Wyman-Gordon case, costs are understated, since they cover only one of that company's four shops at the same location. Amforge is a marginal case, in that modest downward adjustments in costs, upward adjustments in benefits, or a combination of them, could reverse the balance. For Atlas, the balance of costs over benefits is large, but insufficient at the 76 dB level to pass the benefit increase-cost decrease test just noted.[1]

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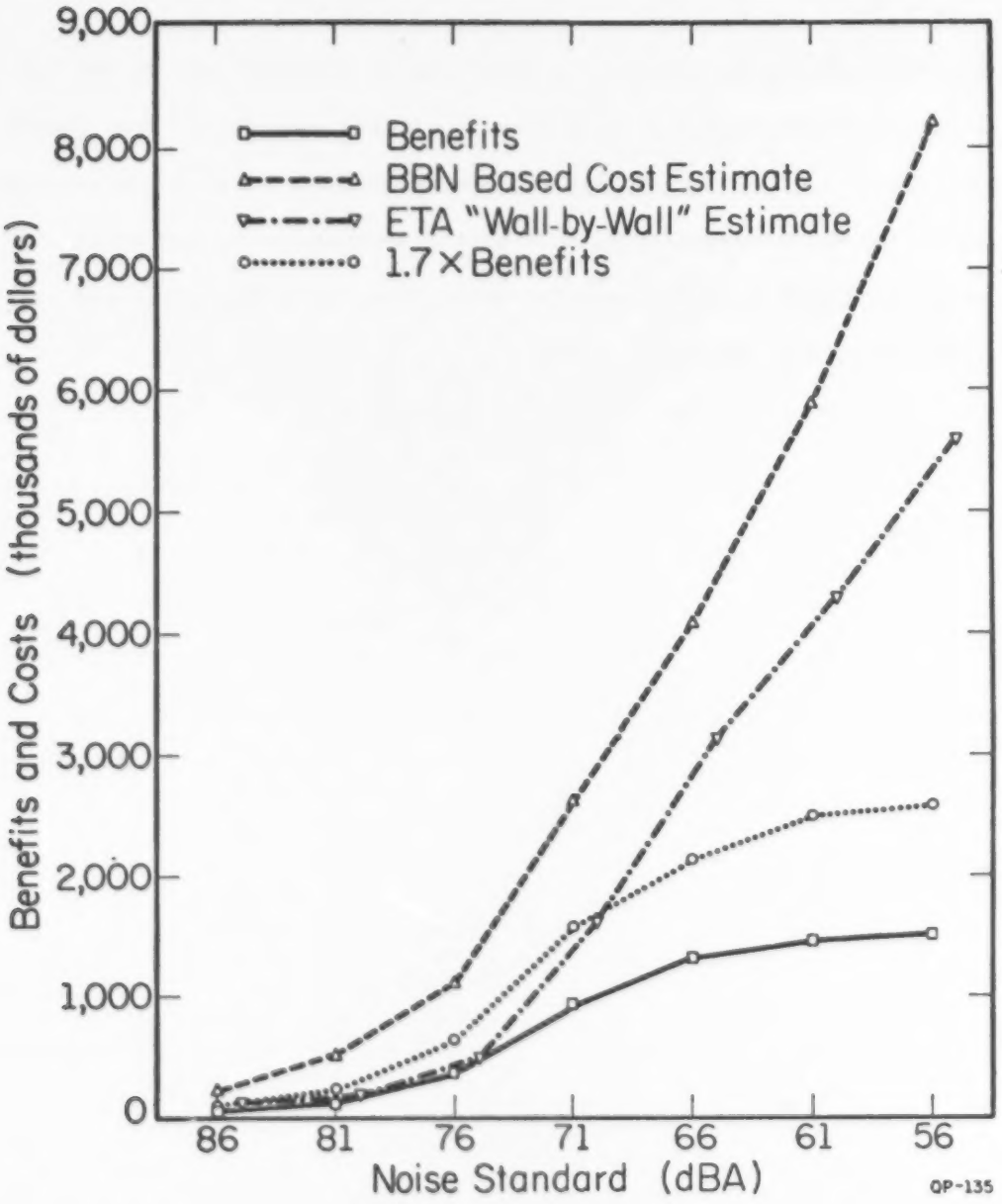
[1] One type of economic remedy that suggests itself where benefits are less than costs is for the source of the pollution or disamenity to acquire from the receiver an easement relating to the unwanted emission. Thus, a forging plant might purchase from surrounding homeowners the right to continue its noise emissions at the currently observed levels. What the plant might actually have to pay for such an easement through a bargaining-negotiating process is not clear. But the average worth of the easement to receivers is measured by the benefit figures shown in the various tables and charts. Suppose, for example, that the noise limit were to be fixed at 61 dB(A). Then the worth to homeowners around, say, Modern Drop Forge of granting easements permitting the plant to continue to emit at its present level of 75 dB(A) would be $83,000, as shown in Table 15. Similarly, on a statewide basis, with 61 dB(A) as the standard, the worth to homeowners of easements permitting all plants to continue their noise emissions at current levels would be $3.52 million, as shown in Table 11, or an average of about $135,000 per plant for each of the 26 plants involved. Such sums, if available, might be thought of as compensation for bearing the burden of unwanted noise or, for some receivers, as contributions toward the expenses of moving to a quieter area.

It does not follow that the actual payment of such compensation would be equitable. Many forge plants have occupied their present locations for long periods of time, and many homeowners would have come to their nearby locations in later years. In these cases, as noted previously (footnote 1, p. 59), they presumably were able to purchase their properties at a discount because of noise damage.

Looking at the totals for each of the standards, costs dominate benefits by large margins, being from three to five times the latter. Though a halving of cost - 1.7X benefits test would not be passed at the 76, 71, and 66 dB levels, the balance in favor of costs appears large. The two sets of totals from Table 15 are plotted in Figure 6, along with the ETA "wall-by-wall" estimates shown earlier in Figure 4. Also shown in this figure is a dotted line representing benefits equal to 1.7 times those in Table 15. Taking note of the limiting case, the 1.7X benefits curve passes above the "wall-by-wall" curve in the 69-85 dB(A) interval. The slopes of these curves indicate, however, that incremental benefits are less than incremental costs at noise standards below 76 dB(A). Putting this limiting case aside, the impression given by the figure, as well as by Table 15, generally confirms those given by Figure 5 and by Tables 11 and 13. The analysis based on the ten-plant group yields ratios of benefits to costs which, on the whole, are somewhat larger than those produced by the statewide analysis. Both approaches, however, consistently produce benefit-cost ratios that fall well below 1.0.

A noteworthy feature of Table 15 is the diversity of outcomes among the ten plants. The benefit-cost ratios at, say, the 61 dB(A) standard range from a low of near zero for DeKalb Forge to a high of 0.86 for Amforge. The cost burdens to achieve any given noise standard also vary widely. Again for a 61 dB(A) standard, the costs to Cornell Forge and DeKalb Forge would be negligible or low, while for seven of



ESTIMATED TOTAL BENEFITS AND COSTS FOR TEN FORGING PLANTS

Figure 6

the remaining eight plants they would exceed $500,000 and, in the case of Wyman-Gordon, would be more than $1 million (for one of four shops). Because of such diversity, the uniform enforcement of a single standard would impose differential burdens on the several plants and would generate highly variable benefits among them, both absolutely and relative to the associated costs.

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APPENDIX I

Impact Evaluation Worksheet[1/]

Cost/Benefit Variable	Error Range[2/]	Degree of Confidence[2/]	Comment
1. Estimated statewide capital costs (Table 3). E.g., $28.11 million for 56 dB(A).	±50%	80%	There are potential error sources in both directions. A few are relatively large.
2. Estimated statewide operating costs (Table 5). E.g., $9.98 million for 56 dB(A).	+35% -50%	80%	Potential errors are tied to capital costs, but more so on the downside.
3. Total costs to reduce noise levels by alternative amounts (Table 6). E.g., $20.83 million for 34 shops to reduce by 10 dB(A).	±50%	80%	Error sources are the same as for the first two items above.
4. Combined cost for 10 plants (Table 8). E.g., $9.32 million for 56 dB(A).	±40%	80%	Estimates are based on greater information on individual plants than statewide estimates.
5. Compliance costs as a percent of sales and payrolls (Table 9). E.g., 4.7% of sales for 56 dB(A) with 5 year amortization.	+50% -70%	75%	Census sales and payroll figures are probably understated.

Cost/Benefit Variable	Error Range[2/]	Degree of Confidence[2/]	Comment
6. Costs to state and local governments. E.g., costs to the state from higher prices of $4400.	+200% -80%	50%	There is uncertainty as to 1) the relative importance of forgings in the goods purchased by state and local governments, and 2) the extent to which cost increases will be passed on to buyers.
7. Costs to Illinois agriculture. E.g., costs from higher prices of $360,000.	+200% -80%	50%	The comment in item 6 above applies here. The underlying figure on annual purchases of agricultural vehicles is also subject to error.
8. Revenue loss to state and local governments from contraction of forging industry.			There are many unknowns. The figures given in the text are illustrative. The loss will in any case be relatively small.
9. Annoyance: At least 15%, or 1100, of the households around forge plants experience significant annoyance.		90%	About 15% of the households are exposed to noise levels of 65 dB(A) (fast meter) or more.

Cost/Benefit Variable	Error Range[2/]	Degree of Confidence	Comment
10. Hearing Loss: About 0.3%, or 21, of the households are subject to possible hearing loss effects from prolonged exposure.		75%	About 0.3% of the households are exposed to noise levels of 80 dB(A) (fast meter) or more outdoors (65 dB(A) indoors).
11. Base Case: Estimates of statewide benefits. E.g., $4.02 million from meeting a 56 dB(A) standard.	±50%	85%	This omits consideration of possible error in the number and distribution of dwellings around forge plants.
12. Total benefits, 10 plants (Table 15). E.g., benefits of $1.52 million from a 56 dB(A) standard.	±50%	85%	The qualification noted in item 11 does not apply here.

1/ This worksheet provides, in abbreviated form, the author's subjective assessment of the accuracy of the major estimates given in the text. The word "subjective" must be stressed, since accuracy in the present case is not generally susceptible of formal statistical evaluation.

2/ The error range, where given, and the degree of confidence must be interpreted jointly. For example, with respect to item #1 on statewide capital costs; an 80% degree of confidence is expressed that the true costs lie within a range of ±50% of the costs estimated in Table 3.

APPENDIX II

Proposals for Revised Noise Standards

A. Forging Industry Association Proposal

BEFORE THE POLLUTION CONTROL BOARD

OF THE STATE OF ILLINOIS

IN THE MATTER OF:	}	
PROPOSED AMENDMENT OF THE NOISE	}	PCB R 76 - 14
REGULATIONS, RULES 101 AND 206	}	

PROPOSAL TO AMEND THE NOISE
REGULATIONS, RULES 101 and 206

Add within the terms defined in Rule 101:

EXISTING IMPACT FORGING OPERATION: Any structure within which impact forging operations do or will occur, the construction of which commenced prior to the effective date of this amended Rule.

NEW IMPACT FORGING OPERATION: Any structure within which impact forging operations will occur, no part of which existed prior to the effective date of this amended Rule, and the construction of which commenced on or after the effective date of this amended Rule.

PROPOSED MODIFICATION TO RULE 206 ON IMPULSIVE NOISE, ILLINOIS POLLUTION CONTROL BOARD RULES AND REGULATIONS.

ADD, FOLLOWING TABLE 5:

Rule 206 shall not apply to Impulsive Noise from impact forging operations but such operations shall be governed as follows:

206(a)

(1) Existing Impact Forging Operations

(A) Existing impact forging operations shall be governed by Table 6 unless subject to Rule 206(a)(1)(B).

(B) Impact forging operations not in compliance with Table 6 on the effective date of this amended Rule shall prepare and file a Noise Control Plan with the Agency and the Board according to the Schedule for Submission detailed below. The Noise Control Plan shall specify the most effective abatement measures available to the individual forging operation which are both technically feasible and economically reasonable.

SCHEDULE FOR SUBMISSION

Forging operations with impulsive sound levels [dB(A)] falling within the categories set forth in the table below shall file a Noise Control Plan within the corresponding time period.

Time for Filing (from the effective date of the Amended Rule)	Measured on Class A Land (Daytime)
Category 1 - 12 months	> 83
Category 2 - 15 months	> 78
Category 3 - 18 months	All others exceeding Table 6

After adoption of this Amended Rule, the Board shall permit the record compiled during such proceeding to remain open to permit hearings on the technical feasibility and economic reasonableness of each Noise Control Plan submitted pursuant to this subsection. The Agency may analyze and prepare recommendations regarding each Noise Control Plan submitted. Any such recommendation shall be filed with the Board and the impact forging operation submitting such plan.

The Board shall, after such hearings, consider and establish appropriate dB(A) sound levels of impulsive sound and a timely schedule for compliance with these levels for each individual forging operation which has filed a Noise Control Plan; provided however, that in no event shall an individual forging operation be required to reduce noise levels below those specified in Table 6. The impulsive sound levels established by the Board for each impact forging operation filing a Noise Control Plan shall thereafter govern such operations, except that in the event that a forging operation alters its operations after implementation of the Noise Control Plan, without altering the physical structure in which the operations occur, then the operation shall be permitted to increase its sound level emissions by not more than 3 dB(A), as a result of such alterations, over the levels established by the Board.

The general information which must be included in the Noise Control Plan may be established by the Agency. The Noise Control Plan shall include, at a minimum, the maximum dB(A) sound levels which will be emitted to receiving classes of land after implementation of the proposed abatement measures, a description of the proposed abatement measures along with data supporting the technical feasibility and economic reasonableness of such measures, and a schedule for compliance. Information included in the Noise Control Plan may be designated confidential by the individual forging operation under the provisions of Section 7(a) of the Act. The requirements for submission of general information established by the Agency, and revisions thereto, shall not become effective until filed with the Index Division of the Office of the Secretary of State as required by "An Act concerning administrative rules", approved June 14, 1951, as amended.

Table 6

No existing impact forging operation shall cause or allow the emission of impulsive sound which exceeds the following levels when measured at any point within such receiving land, provided however, that no measurement of sound levels shall be made less than 25 feet from the existing impact forging operation's property line.

	Class A Land	
Class B Land	Daytime	Nighttime
72	66	56

(2) No new impact forging operation shall cause or allow the emission of impulsive noise which exceeds the allowable dB(A) sound level specified in Table 7 when measured at any point within such receiving Class A or B Land, provided however, that no measurement of sound levels shall be made less than 25 feet from the new impact forging operation's property line.

Table 7

	Class A Land	
Class B Land	Daytime	Nighttime
67	61	51

(3) The land use classifications in effect within a one mile radius surrounding an existing impact forging operation on the effective date of this amended Rule and the land use classifications in effect within a one mile radius of a new impact forging operation at the time construction is begun shall remain the applicable land use classifications for enforcement of Tables 6, 7 and such individual sound levels as may be established by the Board regardless of actual subsequent changes in land use unless such actual changes would impose less restrictive limitations on the impact forging operation.

B. Illinois Environmental Protection Agency Proposal for Revised Noise Standards

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
PROPOSED AMENDMENT OF THE NOISE REGULATIONS, RULES 101, 205, 206 and 209	)	PCB R 76-14

AGENCY'S PROPOSED AMENDMENTS TO RULES 101, 205, 206 AND 209 OF CHAPTER 8, NOISE REGULATIONS, ILLINOIS POLLUTION CONTROL BOARD RULES AND REGULATIONS

The Agency proposed enactment of the following:

Rule 101: DEFINITIONS

* * *

(b) ~~Construction:--On-site-erection,-fabrication,-installation,-alteration,-demolition-or-removal-of-any-structure,-facility,-or-addition-thereto,-including-all-related-activities,-including,-but-not-restricted-to,-clearing-of-land,-earthmoving,-blasting-and-landscaping.~~

A-weighted Sound Level: In decibels, a frequency weighted sound pressure level, determined by the use of the metering characteristics and A-weighted network specified in ANSI S1.4 - 1971 "Specification for Sound Level Meters" and the latest revisions thereof.

(c) ~~Daytime-hours:--7:00-a.m.-to-10:00-p.m.,-local-time.~~

Construction: On-site erection, fabrication, installation, alteration, demolition or removal of any structure, facility, or addition thereto, including all related activities, including, but not restricted to, clearing of land, earthmoving, blasting and landscaping.

(d) ~~dB(A):--Sound-level-in-decibels-determined-by-the-A-weighting-of-a-sound-level-meter.~~

Daytime hours: 7:00 a.m. to 10:00 p.m., local time.

* * *

(g) Fast Dynamic Characteristic: The dynamic characteristic specified as "FAST" in ANSI S1.4 - 1971 "Specification for Sound Level Meters" and the latest revisions thereof.

(The definition of "Fast Dynamic Characteristic" becomes 101(g). The present definitions 101(g) through 101(q) remain unchanged but must be re-designated as 101(h) through 101(r). The present 101(r) "Sound Level" definition is deleted as being unnecessary in view of the new definition 101(b) "A-weighted Sound Level.")

(r) ~~Sound-level:--in-decibels,-a-weighted-sound-pressure-level,-determined-by-the-use-of-metering-characteristics-and-frequency-weighting-specified-in-ANSI-S1.4--1971-"Specification-for-Sound-Level-Meters."~~

* * *

Rule 205: ~~SOUND-EMITTED-TO-CLASS-C-LAND~~

~~Except-as-elsewhere-in-this-Part-2-provided,-no-person-shall-cause-or-allow-the-emission-of-sound-from-any-property-line-noise-source-located-on-any-Class-A,-B-or-C-land-to-any-receiving-Class-C-land-which-exceeds-any-allowable-octave-band-sound-pressure-level-specified-in-Table-4,-when-measured-at-any-point-within-such-receiving-Class-C-land,-provided,-however,-that-no-measurement-of-sound-pressure-levels-shall-be-made-less-than-25-feet-from-such-property-line-noise-source.~~

~~TABLE-4~~

~~Octave-Band Center-Frequency (Hertz)~~	~~Allowable-Octave-Band-Sound-Pressure-Levels (dB)-of-Sound-Emitted-to-any-Receiving Class-C-Land-from~~	
	~~Class-C-Land~~	~~Class-B-Land-and-Class-A-Land~~
~~31.5~~	~~88~~	~~79~~
~~63~~	~~83~~	~~78~~
~~125~~	~~78~~	~~72~~
~~250~~	~~73~~	~~64~~
~~500~~	~~67~~	~~58~~
~~1000~~	~~60~~	~~52~~
~~2000~~	~~54~~	~~46~~
~~4000~~	~~50~~	~~41~~
~~8000~~	~~47~~	~~39~~

Reserved.

* * *

Rule 206: IMPULSIVE SOUND

(a) Except as elsewhere in this Part 2 provided, no person shall cause or allow the emission of impulsive sound from any property-line-noise-source located on any Class A, B, or C land to any receiving Class ~~A, B or C~~ A or B land which exceeds the allowable ~~dB(A)~~ A-weighted sound levels, measured with fast dynamic characteristic, specified in Table 5, when measured at any point within such receiving Class ~~A, B or C~~ A or B land, provided, however, that no measurement of sound levels shall be made less than 25 feet from ~~the~~ such property-line-noise-source.

TABLE 5

Classification of Land on which Property-Line-Noise-Source is Located	Allowable ~~dB(A)~~ A-weighted Sound Levels in Decibels of Impulsive Sound Emitted to ~~Designated Classes of~~ Receiving ~~Land~~ Class A or B Land		
	~~Class C land~~	Class B Land	Class A Land
			Daytime / Nighttime
Class A Land	~~57~~	50	50 / 45
Class B Land	~~57~~	57	50 / 45
Class C Land	~~65~~	61	56 / 46

Rule 206(a) shall not apply to impulsive sound from impact forging operations, but such operations shall be governed by Rule 206(b) and (c).

(b) Except as elsewhere in this Part 2 provided, no person shall cause or allow the emission of impulsive sound from any existing property-line-noise-source involving impact forging operations to any receiving Class A or B land which exceeds the allowable A-weighted sound levels, measured with fast dynamic characteristic, specified in Table 6, when measured at any point within such receiving Class A or B land, provided, however, that no measurement of sound levels shall be made less than 25 feet from such property-line-noise-source.

TABLE 6

Allowable A-weighted Sound Levels in Decibels of Impulsive Sound Emitted to Receiving Class A or B Land from any Existing Property-Line-Noise-Source Involving Impact Forging Operations

Class B Land	Class A Land	
	Daytime	Nighttime
72	61	56

(c) Except as elsewhere in this Part 2 provided, no person shall cause or allow the emission of impulsive sound from any new property-line-noise-source involving forging operations to any receiving Class A or B land which exceeds the allowable A-weighted sound levels, measured with fast dynamic characteristic, specified in Table 7, when measured at any point within such receiving Class A or B land, provided, however, that no measurement of sound levels shall be made less than 25 feet from such property-line-noise-source.

TABLE 7

Allowable A-weighted Sound Levels in Decibels of Impulsive Sound Emitted to Receiving Class A or B Land from any New Property-Line-Noise-Source Involving Impact Forging Operations

Class B Land	Class A Land	
	Daytime	Nighttime
67	61	51

* * *

Rule 209: COMPLIANCE DATES FOR PART 2

* * *

(h) ~~Every owner or operator of Class C land on which forging operations are now conducted shall have three years from the effective date of this Chapter to bring sound from the impact of forging hammers into full compliance with the limits specified in Rule 206 for emissions to any receiving land.~~

Every owner or operator of an existing property-line-noise-source involving impact forging operations

(1) shall have six months from the effective date of this Amendment within which to comply with the standards and limitations of Rule 206(b) of this Chapter, if the maximum impulsive sounds from such impact forging operations exceed an A-weighted sound level of 77 dB when measured at any point within a receiving Class A land, provided, however, that no measurement of sound levels shall be made less than 25 feet from the property-line-noise-source;

(2) shall have twelve months from the effective date of this Amendment within which to comply with the standards and limitations of Rule 206(b) of this Chapter, if the maximum impulsive sounds from such impact forging operations exceed an A-weighted sound level of 68 dB and do not exceed an A-weighted sound level of 77 dB when measured at any point within a receiving Class A land, provided, however, that no measurement of sound levels shall be made less than 25 feet from the property-line-noise-source; and

(3) shall have except as provided in Rule 209(h)(1) and Rule 209(h)(2) eighteen months from the effective date of this Amendment within which to comply with the standards and limitations of Rule 206(b) of this Chapter.